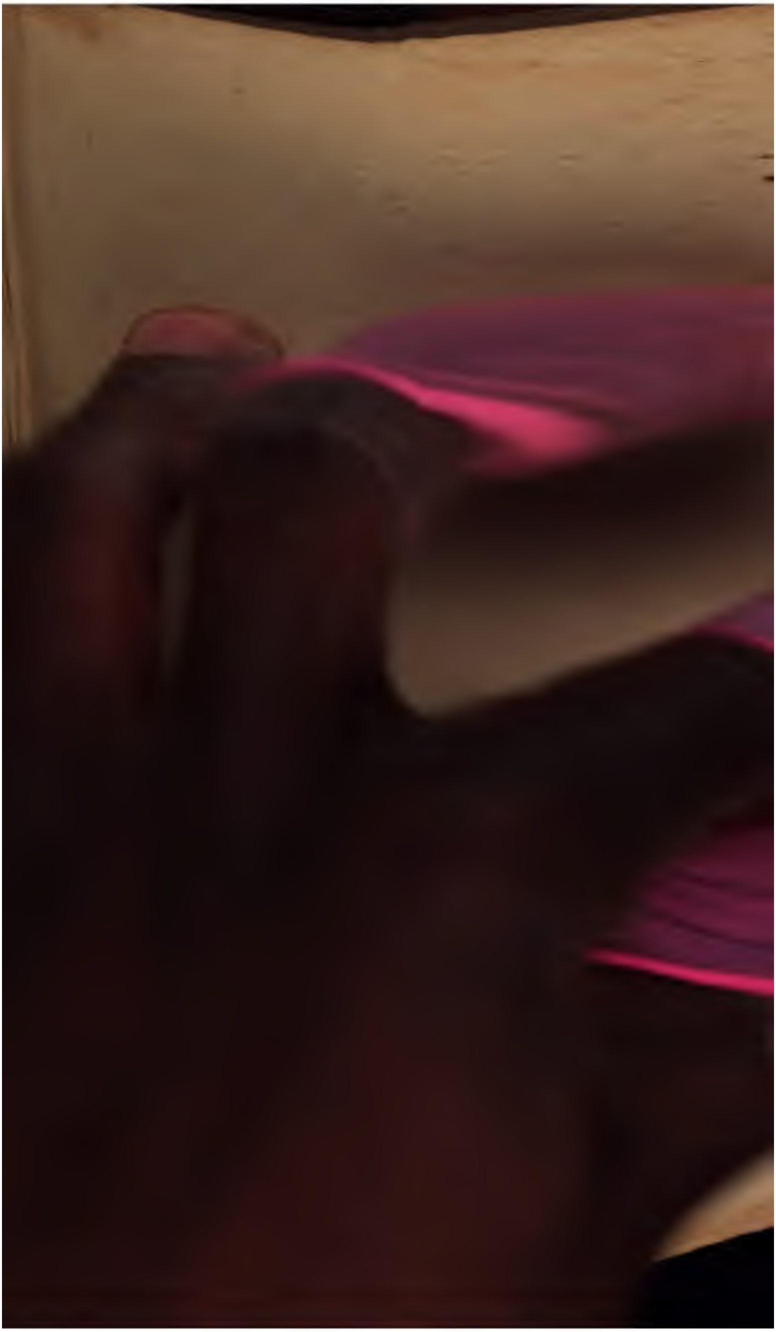

ELEMENTS

OF

PHYSIOLOGY;

BEING

AN ACCOUNT OF THE LAWS AND PRINCIPLES OF THE ANIMAL ECONOMY,

ESPECIALLY IN REFERENCE TO THE

CONSTITUTION OF MAN.

BY

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"Shall the work say of him that made it, He made me not?"

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PREFACE.

A KNOWLEDGE of the structure of the human body cannot but be considered by every cultivated, intelligent, and inquiring mind, as a most desirable acquisition. In tracing the many curious contrivances which are exhibited in its organization, in perceiving the admirable adaptation of its parts to the performance of their varied offices, and in viewing the whole series of its organs in their mutual relation and subserviency, one exercises the highest faculties of his mind, and acquires information that may be useful in life. Indeed, so obvious is the importance of an acquaintance with the mechanism of our bodily frame, that one, viewing the subject in a general sense, might naturally wonder why Anatomy and Physiology are not considered as indispensable elements of education.

The object of the present work is to give such an account of the structure of the animal body, and especially of that of man, as well as of the manner in which the various parts of the machinery operate, as may be readily understood by those who may not previously have directed their attention to investigations of this kind. Science is enriched with several works of great merit on these subjects; but they either are exclusively intended to exhibit a minute and detailed description of the organization, in order to adapt them to the use of persons who, from their profession, necessarily require an intimate knowledge of the size, proportion, and relative situation of the different parts of the body; or else they treat of the functions in such a manner as can only be properly understood by those who have previously obtained considerable acquaintance with the structure. The descriptions, moreover, although sufficiently clear and explicit to those who are familiar with such subjects, are generally loaded with technicalities, and the allusions and illustrations, though readily understood and appreciated by the initiated, are but little adapted to interest or instruct the general inquirer.

Nothing so much distinguishes the present age as the eager desire evinced by all classes of society for acquiring scientific knowledge: the crowds attending public lectures, the number and character of the works on various departments of science that daily issuė from the press, and even the tone of general conversation, sufficiently shew how anxiously information of this kind is sought after. It has been from the conviction that a work like the present is needed, and not from any belief that I am especially qualified for the task, that I have been induced to undertake it. I have, however, endeavoured to the utmost of my power to fulfil the objects in view, to afford such a description of the various structures of the body as may serve to convey a correct idea of their organization, and to give such an account of their mode of action as appears best to accord with experience and observation.

The professional reader will readily perceive that the descriptions are drawn directly from the objects described. Indeed, that I might do justice to the subject, this was the only method that was left me, in attempting to give to the general reader an account of the intricate construction of many parts of the animal machinery. It was impossible to refer to the various sources of information respecting the uses and applications of the different parts; since, though many of the discoverers of physiological truths be well known, appreciated, and justly venerated by the professional student, still their authority and names can have but little comparative interest or weight with those whose attention is less directed to such inquiries. Neither has it been deemed necessary to cite the different views taken as to the use and modes of action of the various organs, nor particularly to insist upon the reason why the opinion adopted has been preferred.

Were mankind a little better informed than they generally are of the constitution of their own bodies, and knew how fearfully and wonderfully they are made, they would be more careful in avoiding causes that tend to disturb and derange the functions; that induce painful and incurable maladies; that contribute to shorten the limited period of human life: and we should have fewer miserable and deluded dupes of ignorant pretension and impudent quackery.

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INTRODUCTION.

General Observations—Classification of Functions—Conservative Functions—Circulation of the Blood—Respiration—Digestion—Nature and Constitution of the Blood—Absorption—Secretion—Functions of Relation—Nervous System—External Senses—Fœtal Life—Concluding Remarks.

THE material world around us comprises two great divisions—the organic and inorganic kingdoms of nature. The latter consists of bodies whose elements are influenced by the laws of attraction, repulsion, gravity, electricity, and other powers, the investigation of which constitutes the provinces of the chemist and natural philosopher. Organic bodies, on the other hand, are endowed with certain powers, in virtue of which they are enabled to resist the influences to which mere dead matter is subject, and to a certain extent to modify and control the properties of matter, so as to render them subservient to their own preservation and development. These controlling powers, laws, or properties, as they have been termed, are called vital, and enable living bodies to resist the mechanical and chemical tendencies of the materials of their composition that, left to themselves, would subvert and destroy the necessary arrangement of their organization.

The living organized kingdom of nature comprehends two grand divisions, the animal and the vegetable; and although at the first glance there seems nothing in common between lordly man and the humble zoophyte, scarcely distinguishable from the rock on which it is fixed, or the simple lichen that clothes the aged tree, yet, on a more close and patient examination, we shall find them performing functions in several respects analogous to each other.

The organs and functions of living bodies may be arranged under the four following heads:—First, Those that contribute to the support and preservation of the individual, which may be termed the Conservative. Secondly, Those whereby living bodies become affected by the external objects around them; namely, of appropriate instruments, the organs of sense, by means of which they are enabled to take cognizance of the impressions received, and the agents of locomotion, comprising together what have been called the Organs of Relation. By a third set of organs, the most effectual measures are provided for the permanent continuation of the race. Lastly, man is possessed of faculties that enable him to trace effects to their causes, to distinguish between virtue and vice, to reflect upon events that have passed, to anticipate the issues of the future; and, above all, to raise his mind to the Supreme Intelligence, the Cause of causes, to whom all nature owes her existence, and to whom, with more or less clearness of conviction, he feels conscious of responsibility.

On the present occasion our attention will be exclusively directed to the consideration of the first two classes of functions, and the machinery engaged in their performance, namely, the conservative, and those of relation.

In the first place, we shall examine into the distribution of the fluids through the different parts of the system, or the *Circulation of the Blood.*

In considering this function, and the apparatus by which it is exercised, we shall find in man, and in those animals most closely allied to him in their organization, that the heart is one of the most efficient agents for this purpose; that it forms, as it were, the fountain-head from which issue forth the vital streams to distribute themselves throughout the whole body, and to which they are again returned. We shall find that by the action of one of its cavities the blood is propelled into a large tube opening into it; that this tube, by its divisions and subdivisions, conveys the blood to every organ and every tissue, in the requisite quantity, and with the due degree of force; that part of the blood is deposited to effect growth and renewal of their textures, part separated in the form of secretions necessary for different purposes, and a third portion thrown off as superfluous or deleterious, thereby purifying the body.

Having been subservient to these and various other functions in the system, the blood will be perceived to have undergone an alteration in appearance and properties: from a bright vermilion hue it becomes changed to a dark purple, and is rendered inadequate to the due performance of the purposes it subserves. It is therefore returned from all parts of the system by another set of vessels, that form reiterated unions with each other, and ultimately terminate by three trunks in another cavity of the heart. Thus, we have two currents of blood in opposite directions, the one proceeding from the heart to every part of the system, the other from all parts of the system towards the heart.

In the next place, by the action of the heart it is forced through the innumerable ramifications of an appropriate tube through the minute tissue of the lungs, where, from the influence of the atmospheric air, and by the extrication of noxious vapours, it becomes purified, and again changed in colour and properties from the dark purple to the vermilion red. Being thus once more prepared for the various uses to which it is applied, it is conveyed to the heart to be propelled to the system.

Such is the incessant course of the blood through the body, from the commencement of life till its termination.

Respiration is the next conservative function to which we shall direct our attention. It is in a great measure subservient to circulation, its chief final purpose being to perfect the blood, to afford an opportunity for the escape of noxious vapours from it, and to impart a portion of atmospheric air necessary to its healthy constitution.

The lungs, the organs directly subservient to this function, are placed without the cavity of the chest. They are of a light and spongy texture, and consist principally of the ramifications of blood-vessels, along with numberless air-tubes that terminate in minute cells. By the alternate enlargement and diminution of the chest, the air in these cells is constantly renewed, receiving from the blood those vapours that are to be carried off by the breath, and imparting to it those elements of its constitution that may be required. The chemical changes that the air suffers in breathing, and the alterations the blood undergoes by exposure to it in the lungs, enable us to appreciate the effects that take place; while the alteration produced upon the blood in the lungs, and the converse change occurring in the system, furnish an explanation of the curious and interesting phenomena connected with the production and regulation of animal temperature.

In the alternate movements that take place in breathing, various interesting muscular actions are called into play, and numerous secondary effects result from the exercise of this important function. Among these the conversion of air into *Sound and Articulate Speech* is not the least curious in the contrivances by which it is effected. At the upper part of the windpipe is placed the apparatus of voice—an apparatus, as we shall find, constructed upon the principles both of the wind and of the stringed instrument, while by the management of the tongue, lips, and other parts, the voice is converted into articulate language.

Our attention will next be directed to the function of *Digestion*, by which food is converted into blood, in order to compensate for the constant expenditure that takes place. Here we shall trace the progress of the food, and the various changes to which it is subjected, from its first introduction into the mouth till it be converted into arterial blood.

In the first place, we find that in the mouth it is reduced by the action of the teeth to a minute state of mechanical division, thoroughly intermixed and combined with the salivary secretions.

It is then transferred to the stomach, where it meets with a peculiar secretion termed the gastric juice, and where it remains for some time, becoming converted into a pultaceous mass named chyme. From the stomach the chyme passes into the intestinal canal, where it is joined by several fluids, such as the bile and other juices, and where a nutritious fluid capable of being received into the system is formed, named chyle.

The chyle is drunk up from the intestinal canal by numerous minute tubes, which convey it through certain bodies, termed lymphatic glands, and afterwards pour it into the veins passing to the heart, in which it becomes mingled with the general mass of blood; and after transmission to the lungs, and exposure to the air, its conversion into arterial blood is completed. Drinks, which undergo no change or decomposition, are introduced in a more direct manner. They are immediately absorbed by the veins, and thus enter at once the general mass of circulating fluids. Various other materials, such as colouring matter, odorous principles, and chemical substances, that resist the influence of the digestive apparatus, are likewise taken up by veins, and carried through the liver, so that while they are filtered through that organ, an opportunity is afforded for their partly being cast out along with the secretion of bile. At all events, they here become subject to intermixture with the blood, and undergo modifications before their introduction into the system at large.

Having taken under consideration the means by which the *Blood* is circulated through the body, the alterations it is subjected to, the manner of its purification, and the mode of its formation and renewal, we shall be prepared to enter upon the examination of its constitution. As might be anticipated, we shall find it a very peculiar and compound fluid, containing, if not all the principles, at least all the elements that go to the formation of the various textures of the body. That besides certain characteristic physical properties, it displays others that neither chemical nor mechanical laws can adequately account for, and which it is conceived must depend upon its vitality. We shall then advert to the function of *Absorption*, and endeavour to point out the means whereby not only fresh materials are introduced, but also how the various worn-out and decayed parts are taken up from the different parts of the system.

Here we shall have to examine a subordinate set of vessels that arise from every organ, and every tissue of the body, of a peculiar structure, exceedingly numerous, freely communicating with each other, and ultimately terminating in the red veins, before these reach the heart. By the action of these vessels, the *Absorbents*, and by other means, the superfluous and decayed parts are carried off, subsequently either to be renovated, or to be altogether rejected and cast out of the body.

The last of the conservative series of functions is *Secretion*. Under this head we shall direct our attention to the various fluids elaborated from the blood, and the character and mode of action of the instruments by which they are furnished, as well as the purposes they serve, either in freeing the system from superfluous or noxious matters, or as they contribute to other useful ends. Some of these fluids are to be considered chiefly, if not entirely, as excrementitious, their evacuation being subservient to the purification of the body by the removal of the decayed and redundant parts. Of this kind are the vapours extricated from the breath, the matter of perspiration from the external surface, several of the secretions poured into the intestinal canal, and the urine derived from the action of the kidneys. Others, again, are furnished for particular purposes,—as the tears to moisten the eyes; the saliva to mix with the food; the gastric juice, an important agent in digestion; the bile, to excite the intestines, and to aid in the elaboration of the chyle; and several others, regarding which it is necessary not only to consider how the secretion is furnished, and the nature of its constitution, but likewise its application to other operations.

Lastly, since from the commencement of life to its termination, the component parts of the body are never the same, but constantly receiving fresh accessions of matter, and rejecting the old and decayed particles, numerous vessels are incessantly engaged in the secretion of the various textures composing the different organs of the body. Thus, in bone the osseous tissue is secreted; in muscle the muscular fibre; in glands their peculiar tissues, and so forth. In every individual part the vessels furnish the characteristic matter required in due quantity, and with the necessary quickness of renewal. After examining the various conservative organs and functions, we shall next turn our attention to those of relation.

The *Nervous System* will first be taken into consideration. In the brain we shall find the organ in which mind and matter become more immediately associated with each other—the especial seat of perception—the source from whence spring the purposes of the will—the throne of the intellectual powers, such as judgment, memory, and reflection.

The nerves will be found to be subservient to various purposes; some of them belonging to the special organs of sense, as sight, hearing, and smell; others conveying the commands of the will in order to bring into action the muscles that obey its influence; others transmiting to the seat of perception the impressions made upon the different parts of the body; while some are connected with instinctive movements; and others, again, appear to be more immediately subservient to organic life.

The knowledge we possess of the mode of action of the different parts of the nervous system is less clear and determined than of most other parts of the body. Yet the functions to which they evidently contribute are of such high and paramount importance:—they are so essential to the exercise of other organs, contribute so much to the combination of the different parts of the system into one harmonious whole, and are so characteristic of the higher organized animals, that their structure and uses cannot fail to excite interest. Although, therefore, we may be unable to point out the uses of the various parts, we shall endeavour to give such an account of their structure and distribution as may convey to the general reader a correct view of the whole. At the same time we shall be cautious in entering upon the merits of the various discordant opinions that have been and are at present entertained respecting this interesting portion of the animal frame.

The organs of the five external *Senses* will in the next place occupy our attention. The construction of these instruments is so admirable, the uses of many of their parts so obvious, and the beauty of the mechanism so striking, that they have attracted the attention of the most superficial observer. In tracing the connexion between the mechanism and the result of its action, it will be a pleasing task to point out the many evidences of design afforded, the excellency of the contrivances, and how much these senses contribute to the preservation, enjoyment, and welfare of the animal.

The means by which animals are enabled to re-act upon the external world, to perform the various motions so essential to the exercise of various other functions, to avail themselves of the power of locomotion, to fix their attitudes, and to vary their postures and gestures, depend upon the *Muscular System*;—in connexion with which we shall consider the bones, the manner in which they are bound together by ligaments, and several other structures that contribute to these purposes.

Before leaving the animal mechanism, we shall direct our attention to the various steps of its *Formation* and *Development*, from its first rudimentary state, while it is still connected with the parent, till its final separation from the principle of life in old age, and when in death the body is yielded up to mechanical and chemical influences and laws.

Many of the functions of the human body would have been still unknown and unappreciated, had it not been from observations made on the structures and uses of the different parts in the lower animals: indeed these yet afford the principal sources from whence the facts are derived, not only for confirming what has been already ascertained, but for affording the means for extending physiological knowledge. The functions in the human body have long ceased before we can presume to examine them. But in the lower animals it is different: we are able to examine them even in the living state; we can place them in various conditions best calculated to exhibit them in action; and, moreover, we obtain valuable information from the various modifications of structures as to size, proportion, and relation in the different classes, orders, and families of animals. Accordingly, we shall avail ourselves of these rich sources of physiological truth, and advert to the numerous interesting and curious contrivances displayed in these structures, wherever they seem calculated to throw light on corresponding organs and functions in the human subject.

The study of no department of science affords so many clear, striking, and irresistible proofs of the attributes of the deity, as that which has for its object the consideration of the animal structure, and the mode in which its functions are carried on. Take, for example, any single organ of the animal machinery—the eye, or the ear, or the organ of voice—examine its mechanism, study its adaptation to the office it has to perform, observe it in operation; and where can there be found more direct, more explicit, and more irrefragable evidence of foresight in the design, benevolence in the purpose, and wisdom in the contrivance? It is said to have been in consequence of such studies that the celebrated Grecian physician and philosopher Galen breaks forth in the following beautiful apostrophe—"In explaining these things," he says, "I esteem myself as composing a solemn hymn to the author of our bodily frame, and in this I think there is more true piety than in sacrificing to him hecatombs of oxen and burnt-offerings of the most costly perfumes; for I first endeavour to know him myself, and afterwards to show him to others, to inform them how great is his power, his wisdom, his goodness."

However worthily Galen thus expresses himself when contemplating the Great Author of all, and however far in this respect he surpasses the most distinguished of his heathen predecessors in a rational view of the character and proper worship of the Deity, it is not to be forgotten that though educated amidst the darkness of idolatry, and although there be no reason to believe that he ever laid aside its delusions, yet he was born in A. D. 131, at Pergamos, where was established one of the seven churches of Asia, and where the gospel had already widely spread. It is impossible to conceive of a man of his acute, inquisitive, and penetrating mind, with such a thirst as he displayed for the acquisition of truth, that he could have overlooked, or have been altogether ignorant of the light which had already begun to shine forth around him, and which was to dissipate the darkness and gloom that had so long overwhelmed the intellect of man, as if to show that however great the original talents and endowments, however vast the acquirements, or however penetrating the judgment, these of themselves could never have attained to a just conception of the condition of man, and the true character of the Creator and Preserver of the universe.

But when a knowledge of God has been obtained from higher sources, how much does the contemplation of his works, as displayed in the animal economy, contribute to confirm the truth that is revealed! how numerous are the instances afforded of superintending providence, of infinite power, of universal beneficence, wisdom, and foresight!

CHAPTER I.

CIRCULATION.

General View of Circulation—Opinion of Hippocrates—Theory of Harvey—Discovery of the Absorbents—Structure of the Heart—Condition at the point of death—Structure and Action of the Arteries—Of the Capillaries—Of the Veins—Operation of Transfusion—Heart an involuntary organ—Heart insensible—Effects of the Passions of the Mind—Size of the Heart in proportion to the other Organs—Mechanical conditions of the Blood Vessels—Circulation influenced by Respiration—through the Brain—in the Abdomen.

In all animals the blood is subjected to motion, more or less rapid in each after its own kind; the agents by which the motion is produced, and the channels through which the blood is conveyed, being most perfectly adequate to the purposes intended, and these purposes admirably adapted to the circumstances under which the animal is destined to be placed. In the more highly organized beings, such as man, mammalia, and birds, from birth throughout life, the agents which put the blood in motion are constructed upon the same general plan, and produce results similar in all. An acquaintance, therefore, with the structure in one species will enable us to acquire a correct general notion of what obtains in the whole. The description we have now to submit will have especial reference to the organs of the circulation of the blood in man. These instruments are the heart, arteries, capillaries, and veins. A general view of these in the first place, will enable the reader fully to understand the more detailed account, which it will be necessary subsequently to present.

The heart is composed of four cavities or pouches, which alternately receive and propel the blood. The walls forming these pouches are composed of fleshy fibres curiously interwoven. Two of the cavities are termed auricles, the other two ventricles. An auricle and a ventricle being placed towards the right, therefore are named the right auricle and ventricle; while the others, being placed on the opposite side, are called the left. It is ascertained that the blood from all parts of the body is conveyed to the heart by the veins, which pour it into the right auricle. The auricle throws it into the right ventricle, by which it is propelled to the lungs through an artery. In consequence of this artery, by its thousands of branches conveying it to the lungs, it is called pulmonary. Having been exposed to the air in the lungs, and after undergoing important changes, it is received by another set of vessels, the pulmonary veins, which pour it into the left auricle by four trunks; the auricle then delivers it to the left ventricle, by which it is forced into the aorta, the great artery of the system, to be distributed to every part of the body, there to furnish new materials to compensate for that which becomes worn out—to sustain the vital action of the different organs of the body—to supply the various secretions, and maintain the vital heat. Having performed these and other important purposes, it undergoes a change the reverse to that which took place in the lungs. While passing through the lungs one of the most evident changes effected upon it is from the dark purple to the vermilion red, while here the converse takes place, from the vermilion red to the dark purple; after which it is taken up by the veins to be conveyed to the right side of the heart, from whence we started. This course of the blood, of which the above is a general outline, is termed the circulation, in which we see it flowing from all parts of the system to the right side of the heart, to be sent to the lungs, and flowing from the lungs to the left side of the heart, to be sent to the system, constituting what is termed the complete circulation. But the lesser and greater circulations are also often spoken of, the former being applied to its transmission from the right to the left side of the heart, through the lungs, the latter to its course from the left through the system to the right side again. The circulation, as described, has been compared to the figure of eight;—the upper smaller division representing the lesser, the lower the greater circulation. The double lines, *a a*, to the right, will represent the extent of the scarlet or vermilion-coloured, and the dark line, *b b*, the purple-coloured blood. Such is a general sketch of the circulation of the blood in the most perfect animals, as first ascertained and demonstrated by our countryman the immortal Harvey, as he has been justly termed.

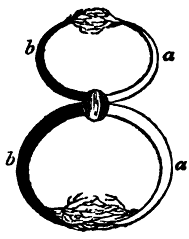

FIG. 1.

That we may adequately appreciate the importance of Harvey's discovery, it is necessary to consider the state of knowledge previous to his time, and the important results which subsequently accrued to all departments of the healing art. In the repugnance which every one feels to the handling of the dead body, especially that of a human being, there exists a powerful natural obstruction to the study of the architecture of our frame, and the manner in which its many curious functions are performed—a repugnance so strong that with most men it requires no small effort of reason to overcome it, while with others even the experience of years cannot entirely subdue it. If to this be added religious prejudices and superstitious fears, not altogether overcome even in these days of boasted enlightenment, we shall not be surprised that the ancients knew so little, but rather that they acquired so much knowledge of the structure of the body, when we recollect the opinions, convictions, and practices which obtained among the nations by whom the sciences were first cultivated. The embalming of the dead among the Egyptians, the killing of animals for food and for sacrifice, as well as the practice of auguring, in order to foretel future events, by the inspection of the viscera of animals, and sometimes it is said even of human victims, have all been brought forward as means whereby a knowledge of the structure was acquired. The hurried manner, however, in which such investigations were necessarily conducted, precluded a sufficiently minute examination, and the warmth of the climate presented another difficulty. When we inquire of those among ourselves who slaughter animals for our food, we find that they are in reality as ignorant of the beautiful contrivances that are daily before their eyes as the mower is of the structure of the grass which he cuts down, or the miner of the wreck of former worlds that may lie scattered at his feet. Need we wonder then that Hippocrates, the father of medicine, who flourished in Greece about four hundred years before the Christian era, believed that the left side of the heart and the arteries contained air? This opinion arose from the circumstance that they are found empty after death, for a reason which will afterwards appear.

The celebrated Galen, who flourished about A. D. 130, and who seems to have been deeply embued with the proper spirit of philosophical investigation, though not the first to suggest, was the first fully to establish the fact, that the left side of the heart and the arteries contain blood in the living body; but he believed that the blood flowed backwards and forwards in the same vessels, like the tide upward and downward in a river. We need not here advert to the torpid state of the human mind in what are termed the dark ages.

On the revival of learning, in the fifteenth century, we find the learned chiefly engaged in commenting upon, and blindly adopting the errors as well as the truths of the Grecian sages. Bolder spirits soon began to observe and think for themselves. In 1572, Fabricius, then professor of anatomy at Padua, at that time the most celebrated school of medicine in Europe, taught the structure of the valves in the veins. Harvey, who resorted to Padua for the study of medicine, was dissatisfied with the explanation given of the function of these valves by Fabricius. On his return to England, where he diligently prosecuted his inquiries, being countenanced by Charles the First, and allowed deer from the royal park for the purposes of his investigations, he soon satisfied himself respecting the course of the blood, and in 1628 publicly announced his great discovery. It is to be observed that Harvey detected no new part: all the organs had been named and described, most of them two thousand years—and all of them before he was born. The materials had all been collected, but hitherto no architect had appeared to arrange them in order. Deductions certainly had been drawn, and conclusions had been arrived at. These were handed down from teacher to pupil, without question or examination, till our illustrious countryman burst the barriers of prejudice and dogmatism, first drew the legitimate inferences, and by a strength of argument and clearness of evidence which have never been surpassed, established the truth of his doctrine.

It may be scarcely necessary to state that this great discovery, this true explanation of the manner in which the blood flows through every organ of our body, produced a great change, nay, a complete revolution in medical opinions and practices. But this did not occur at once: preconceived opinions, envy, and ignorance had to be overcome. He afterwards, in the language of complaint, states that his discovery prejudiced him in his private interests, and in the eyes of his professional brethren, none of whom above thirty-six years of age could be induced to believe in the truth of the doctrine. That we may have some idea of the debt of gratitude due to Harvey by posterity, it may be sufficient to refer to the great changes that have taken place in the performance of surgical operations, in consequence of which much human suffering has been alleviated, and many useful lives prolonged.

In order to avoid the mention of too many objects at once, we have as yet taken no notice of a set of vessels termed absorbents, of the existence of which Harvey was ignorant. Indeed, he himself furnishes us with a notable example of how slowly we adopt new views in advanced life, and how unwilling we become of having our long-cherished opinions overturned, and new ones substituted in their place. In the daily waste to which our bodies are subjected, there arises the necessity for the introduction of new materials, which are furnished by the food and drink. These, after undergoing the necessary processes of preparation by the digestive organs, are taken up and conveyed into the general mass of circulating fluids. Again, all the organs in our body, even the hardest bones, are constantly undergoing change; the older materials are removed, and fresh ones are deposited in their stead; so that in the course of time, with perhaps the single exception of the enamel of the teeth, not one atom or smallest particle of matter which composed our bodies a few years ago now remains in us. These old worn-out particles are taken up by appropriate vessels, carried into the general circulating mass, and subsequently cast out through the proper channels. Both of these offices, that is, the introduction of new, and the removal of old materials, were believed to be performed by the veins, till an Italian anatomist, Acelli, on opening a live dog, observed numerous small tubes conveying a whitish fluid of a sweet taste from the intestinal tube. This was the chyle or new fluid furnished by the organs of digestion, and which, from its resemblance to milk, was called the lacteal fluid, while the vessels transmitting it were named the lacteals. This discovery was announced by Acelli in the year 1622. Yet Harvey could not be induced to believe in their general existence in the animal system, but continued to hold by the old doctrine of venous absorption. Subsequently another set of absorbents, which, from the extreme thinness and transparency of their coats, had escaped notice, were discovered to arise from almost every part of the body, and believed to exist universally. As they generally convey a colourless fluid or lymph, they are named the lymphatic absorbents. Both sets of absorbents terminate in the veins before these pour their contents into the right side of the heart. Their use and mode of action will be hereafter considered under the head of absorption. It is necessary at present to advert to them, in order that the reader may be able to understand allusions which may be made in reference to them.

In warm-blooded animals, as man, mammalia, and birds, the heart may be considered as double,—the right heart receiving the blood from the system at large, and transmitting it to the lungs, while the left receives it from the lungs, and transmits it to the system. During each complete circulation, the whole mass of blood is exposed to the influence of the air in the lungs. In cold-blooded air-breathing animals, or reptiles, such as tortoises, turtles, frogs, lizards, serpents, the heart is single, that is, has only one auricle and one ventricle,—the auricle receiving the blood both from the lungs and from the system, and delivering it to the ventricle, which propels part to the lungs and part to the system, so that a portion only of the blood is exposed to the influence of the air. A third modification is found in fishes: In them the heart is single, as in the amphibia, but the auricle receives the blood from the system only, and delivers it to the ventricle, which propels it to the gills, or organs analogous to the lungs of air-breathing animals. While filtered through the minute ramifications of the artery by which it is dispersed through the gills, it becomes exposed to the water, holding a portion of air in solution. From the gills it is collected by numerous small vessels. These terminate in a common trunk, which proceeds to transmit the blood to all parts of the system, without the intervention of either an auricle or a ventricle. The whole mass of blood, therefore, in each complete circulation becomes exposed to the influence of the aerated water. We thus find that the single heart of amphibia performs the office of both the right and left heart of warm-blooded animals by a combined action, while the single heart of fishes performs that of the right only. The importance of these modifications will be hereafter better understood, when we come to discuss the nature of the changes which the blood undergoes in the lungs and in the system respectively, the sources of animal temperature, and the rank each class holds in the scale of intelligence.

As has been mentioned, the canals by which the blood flows, and the direct agents of its circulation, are the heart, arteries, capillaries, and veins. We shall now proceed to examine each of these separately, after which we shall be prepared to consider their combined operation. The heart is situated nearly in the centre of the chest; it is somewhat pear-shaped, with its base or broader part upwards, inclining backwards, and to the right,—its apex or point being forwards, and to the left. In consequence of the apex being more superficial, and less covered by the lungs, its beating is found under the fifth left rib, hence the popular opinion that it is placed in the left side. It is a powerful and very peculiarly constructed muscle, or rather a combination of muscles, the fibres of which are intricately interwoven with each other. Externally, it is covered by a dense membrane, which firmly adheres to the substance of the heart, and is reflected, so as to form a capsule or bag. The internal surface of this capsule constantly exhales a thin watery vapour, which preserves the surfaces moist and slippery, whereby the incessant motions of the heart are facilitated, and the effects of friction obviated. The internal cavities of the heart, and indeed the internal surfaces of all the blood-vessels, are similarly dense and smooth, and in a like manner bedewed with moisture, so that the blood glides along, meeting with the least possible resistance. The right auricle, which receives the blood brought by the veins from all parts of the system, is placed on the upper and right side of the heart. On slitting it open the termination of the two great veins of the body are readily perceived. They are termed the superior and inferior cavæ, or great hollow veins. The former returns the blood from the head, superior extremities, and chest; the latter from the lower parts of the body. A third pours in the blood which had circulated through the substance of the heart itself, this being the only one of the three furnished with a valve for the prevention of the return of the blood when the auricle exerts its expulsive force. A fourth wide orifice communicates with the right ventricle, named the right auriculo-ventricular opening.

Let us now consider what occurs in the action of these in the living state. The three veins just mentioned pour the blood into the auricle until it has reached that degree of distension at which contractile or expulsive power is excited. On this being exerted, at first sight there is nothing to prevent the blood from being thrown back again into the veins, excepting in that from the heart, which possesses a valve. The constant current of blood in the cavæ, however, will oppose this return; and what is more, there is no impediment to its passage into the right ventricle, but rather it is solicited or drawn into the ventricle by a power which must here be explained,—a power which furnishes us with one of the innumerable striking examples of the vast superiority of living mechanism over any thing that the ingenuity and patient industry of men can accomplish. The cavities of the heart are not only endowed with the property of contraction, so as to expel their contents like a forcing pump, but likewise with the property of dilatation, so as to a certain extent to draw the blood into them like a sucking pump. It must be borne in recollection that the expansion of these cavities is not passive, but active; that is, they are not expanded in consequence of the blood poured into them, but they dilate that they may receive the blood. Hence it follows that while the right auricle is contracting so as to force out the blood, the right ventricle is dilating in order to receive it. We may have a good example of this active power of dilatation in cold-blooded animals, such as a turtle or shark, where, on the removal of their heart immediately on capture, it continues to dilate and contract for many hours after, even when thus detached, and altogether empty; and if we grasp it with our hand, we shall experience convincing proof that it is by no means passive during dilatation. Were it not that the different parts of the heart thus beautifully co-operate to bring about the same end, the languid current of blood in the veins might not be able to overcome the passive contracted state of the auricle, nor the comparatively weak contractile power of the auricle to force it into the more muscular ventricle. But no such want of adjustment exists in this machinery, for all its parts harmoniously work together for the intended purposes.

The right ventricle, which receives the blood delivered over to it by the auricle, is placed on the right, inclining forwards. On opening it a very beautiful valvular apparatus will be found, named tricuspid, commanding the auriculo-ventricular opening: it is composed of a fold of the dense lining membrane. Into the margin of this fold are fixed several threadlike cords or tendons, which proceed from fleshy bundles connected with the walls of the ventricle. Behind this valve, leading upwards, is placed the orifice of the pulmonary artery, which distributes the blood to the lungs. Here and there, crossing from one part of the ventricle to another, tendinous cords may be observed, which tend to prevent over-distension, and also small transverse fleshy bundles, which aid in the contraction of the ventricle. The observer will remark that the walls of the ventricle are thicker, and altogether more powerful than those of the auricle; and the reason of this is obvious, for whereas the auricle has merely to deliver the blood to the ventricle, the ventricle has to force it through the numerous divisions and subdivisions of the pulmonary artery. On the contraction of the ventricle the fleshy parts of the valvular apparatus, which are connected with, and indeed form a part of its walls, are simultaneously thrown into action, so that by means of the little cords the valve is so placed as completely to shut the auriculo-ventricular opening, and thus effectually prevent any return of the blood into the auricle; at the same time the orifice of the pulmonary artery offers no obstruction, and into it the blood is propelled.

Now, arteries are tubes possessed of very considerable elasticity, whereby, on a fluid being thus impelled into them, they admit of expansion. By the same elastic power, independently of any other contractile power they may possess, they act upon the column of blood forced into them; consequently, on cessation of the contraction of the right ventricle, the blood would be thrown back upon it, were it not that at the orifice of the pulmonary artery are placed three little valves of excellent mechanical contrivance. They are of a semilunar shape, and are so named. They are lodged in slight depressions, their free edges being along the sides of the artery, and in the centre of the margin of each there is a small lenticular piece of cartilage, which prevents the too close application to the surface of the artery, so as to admit of the entrance of the blood behind them, when it is requisite they should be raised in order to perform their office. They offer no resistance to the course of the blood from the ventricle into the artery, but on the reaction of the artery on the column of blood, part of the blood gets behind these valves, and raises them, whereby a complete barrier is formed to the return of the blood into the ventricle; it must therefore keep its onward course through the lungs. These valves act altogether mechanically, and consequently act efficiently even in the dead body. If a tube be put into the artery, and an attempt made to inject the ventricle from it, the valves will be found immediately to be raised, and thus prevent one drop from entering the ventricle. There is a marked difference between the semilunar and tricuspid valves; the latter, being thrown into action by its appropriate muscular fibres, does not act in the dead body, but performs its office only as a vital agent, and, intimately connected as it is with the walls of the ventricle, it co-operates with it. On the other hand, the semilunar valves are called upon to prevent the action of the artery from being exerted upon the blood in one direction, which action is principally, if not entirely, the result of mechanical elasticity.

Soon after the pulmonic artery leaves the heart it divides into two, the one proceeding to the right, the other to the left lung. On entering the substance of the lungs they begin to send off branches, until by reiterated subdivisions they ultimately become as minute as the hairs of the head, and are therefore termed capillary. These capillaries either communicate with the capillaries of the pulmonary, or continuously become the venous capillaries. It is while the blood is filtered through these minute tubes, and exposed to the air in the lungs, that it undergoes the important changes to which we have alluded: it is here its purple colour becomes scarlet, and other changes occur, which can only be understood when we come to discuss respiration. In the meantime, it may be mentioned that notwithstanding the great body of blood passing through the lungs in the pulmonary artery and veins for especial purposes, that blood does not appear to be fitted for general purposes, such as nutrition and secretion, consequently other arteries and veins are distributed through the lungs, to which the name bronchial is applied. After the blood undergoes the change, the venous capillaries unite into branches, and these into others, until by successive unions the blood is collected into four trunks, two from each lung. These pour it into the left auricle, which delivers it to the left ventricle, from thence to be propelled into the aorta, the great arterial trunk of the system, by the divisions and subdivisions of which the vital stream penetrates every organ and every tissue of our bodies, to sustain their life, their energies, and their vital warmth. It would be an unnecessary repetition minutely to describe the left side of the heart, since both are constructed upon the same general plan. The same relation subsists between the auricle and the veins and between the auricle and ventricle. A similar valvular apparatus commands the left auriculo-ventricular opening as on the right side. From a fanciful resemblance to a bishop's mitre, it is named the mitral valve. So also are there three valves to guard the entrance of the aorta, like to those of the pulmonary artery—these six constituting all the valves belonging to the arterial system. There is one circumstance which the observer will not fail to notice, that is, how much stronger the left side of the heart is than the right, especially the ventricle: its walls are much thicker, their texture more dense and compact, and evidently capable of a much greater degree of exertion. Nor will this excite surprise, when it is recollected that the right ventricle has merely to propel the blood to the lungs by tubes similar in their mode of distribution, penetrating an uniform structure which performs one function, and that little liable to disturbance from external causes; while the left ventricle has to force the blood to the furthest extremities of the body, through every variety of vascular distribution, into organs of every variety of texture, where very different functions are carried on, and to parts where the circulation is exposed to numerous external disturbing causes. Here, then, as everywhere else, are the means adapted to the ends.

It has been stated that the ancients believed that the left side of the heart and the arteries contained air, and that this opinion arose from the circumstance of their being found empty after death, while those of the right are generally gorged with blood. The cavities of the left side will also be found smaller than those of the right. These differences appear to be best accounted for by the occurrences which take place at the point of death. Death seldom occurs throughout the whole of our organs simultaneously, but one link of the chain which connects us with life is broken after the other; nor are the approaches of death made always in the same direction, sometimes one and sometimes another of the functions on which life more immediately depends ceasing to perform its office before the rest, and thus commencing the first part of the last inevitable scene which closes our connexion with this world. The cessation of the blood's motion is generally the last to take place, nor does it occur at the same instant through the whole series of the agents by which it is put in motion. Here, too, one part ceases to act before another. The left side of the heart and the arteries appear to be endowed with a greater degree of vital energy and tenacity of life, for as they are among the first, if not the first, to be called into operation at the commencement of life, so are they among the last to cease action at its close. They continue to force onward the blood into the passive veins, where part stagnates, and part reaches the right side. At the same time the powers by which the movements essential to breathing are produced begin to fail. There is now an obstruction to the passage of the blood through the lungs; it accumulates therefore in the right side of the heart, which thus dies in a state of distension, while the left ceases to act in the state of contraction. In order to reverse these conditions in a live dog, the veins entering the right auricle were tied, so as to prevent the entrance of blood into the right side; and at the same time the aorta was tied, so as to prevent its escape from the left. The animal thus died with the right empty, and in a state of contraction, while the left was gorged, and in a state of dilatation. The very reverse was now found in the relative size of the two sides,—the right was the smallest and the left the largest. The inference therefore is, that in a living healthy state both ventricles are of the same capacity, and indeed this is nothing more than what might have been expected; for had it been otherwise, a want of proper adjustment between the two would have been the consequence. The limits of the ventricles are accurately defined by the valves; but the limits of the auricles are not so well marked: they are however of at least equal capacity with the ventricles. With regard to the order in which they respectively contract and dilate, the two auricles simultaneously perform these functions, as do also the ventricles, for it will be obvious that the auricle and ventricle of the same side could not well contract or dilate at the same instant without disturbance, while both auricles and both ventricles may.

Without at present entering upon other points relative to the heart, we shall now follow the blood through the larger circulation, so as to complete its course. The aorta arising from the base of the left ventricle, ascends, inclining to the right, till it reaches the upper part of the breast-bone, where it makes a remarkable turn towards the left, till it rests upon the third vertebra of the back. This is termed its arch. It then descends through the chest, enters the abdomen, continues to rest on the vertebral column, till it reaches the fourth vertebra of the loins, where it divides into two, a right and a left branch. The first branches it gives off are two for the supply of the heart itself. From the arch are given off those which proceed to supply the head and upper extremities, while in its descent in the chest it gives off its streams to the walls of the chest and remaining viscera. Within the abdomen, before its division, it furnishes the branches which supply the walls and viscera of that cavity; and lastly, its divisions are distributed to the contents of the lower abdomen and inferior extremities. All these branches which this main trunk gives off, with their numerous subdivisions, in some instances even to the fifth, sixth, seventh, and eighth divisions, are accurately traced and named, either singly or in groups, till they amount to several hundreds; and not only this, but their relative position with respect to other organs, the varieties in size, or mode of distribution to which they are subjected, are treasured in the memory of every properly-educated and accomplished professional man. But the millions and millions of smaller divisions which we know must exist, are far beyond the grasp of our finite minds to comprehend. We know that there is not a point of the various surfaces of our bodies that the point of the smallest needle can penetrate without wounding thousands of these minute tubes, and that a single grain of sand is considered equal to cover millions of their ultimate extremities. Need we, then, look to microscopic objects alone for evidence of the apparent infinite minuteness of creative power? Is there not indeed in every fibre, in every tube, and in every globule of which our bodies are composed, an equal evidence of the same truth furnished to us?

Arteries do not always take the most direct course to their destination, but always the safest, and where they are least liable to be interfered with in their office. It would be difficult, if not impossible, to shew any course that the aorta could have pursued, possessed of so many advantages as may be shewn to result from the very course which it takes, and whatever modifications and deviations it may present in other animals, they will always be found to be made for the best possible reasons, and followed by the best possible results. In crossing joints, the main trunk is found in the flexures, where it is more safely lodged, and less liable to injury than it could have been anywhere else. Of such designs the main artery of the thigh may be taken as an example. Immediately on escaping from the cavity of the lower abdomen it is found in the front of the groin; as it proceeds downwards (where, if it continued in the same direction it would be much exposed to injury), it sinks deeper, and runs inwards, so that before it reaches the knee it is found behind, securely lodged in the flexure of that joint, protected by the projections of the bones and the hamstrings.

The arteries are not composed of one substance, but of three different tissues, in concentrate layers or coats, as they are termed: the internal is smooth and lubricated with thin secretion; the external is constituted of the cellular or interlaced tissue, chiefly for the purpose of imparting strength, and connecting them with neighbouring parts; the middle layer, which is the thickest, is cream-coloured, disposed in fibres, and highly elastic. It is upon this coat that the effect the arteries have upon the motion of the blood depends. Contrary to what might have at first been expected, its thickness, elasticity, and contractile power is not in proportion to the size of the artery, but it is proportionally thinner, less elastic, and contractile in the larger than in the smaller.

From the properties possessed by the middle coat, the blood-vessels are enabled to accommodate themselves to many varying circumstances. If we bleed an animal to death, as the quantity of blood diminishes, so do the arteries contract and exert a certain degree of tension upon the blood they contain, and the slower the blood is withdrawn, the more completely will they adapt themselves to the diminished quantity, and more effectually exert their tension upon it. Accordingly, as it is frequently the object with the medical practitioner to diminish this tension in disease, he bleeds his patient from a large orifice, and sometimes opens two veins at once, that he may gain the relaxation he desires with the smallest expenditure of blood, knowing that it is not so much by the quantity of blood shed, as by the effect produced on the organs of circulation that advantage accrues, and that the speedier the blood is withdrawn the more certain will be the effect. When a limb is amputated, the thigh for example, the surgeon does not find it necessary to tie many arteries: the principal branches only require to be secured, the others by their contractile power or tonicity, as it is called, close their cut extremities, and arrest the hæmorrhage. In the same way, daily experience teaches us that the bleeding from slight wounds soon stops; but were it not that the arteries are endowed with this property, the merest scratch might prove fatal, for where the vessel is so situated as that it is prevented from exerting this power of contraction, alarming and even fatal hæmorrhage may occur from a very small twig. Thus, in the extraction of a tooth the bleeding is occasionally suppressed with great difficulty; and if the tonicity be impaired, or originally deficient, patients have been known to bleed to death from very slight wounds, strongly impressing upon us how much we are indebted to this conservative power of the blood vessels. After amputation all the vessels shrink to a size sufficient to exert the necessary tension upon the diminished quantity of blood required by the stump.

Another example of adaptation to circumstances is furnished in the operation for the disease named Aneurism, in which a tumour is formed in the course of an artery, and which, if left to itself, might burst and prove fatal. Here the surgeon cuts down on the main artery, and applies to it a ligature, so as to cut off the supply to the tumour. At the place where it is tied, the vessel is finally obliterated, and the tumour gradually disappears. But how, it may be asked, is the limb below the part where the main channel was closed now supplied? The answer is, there are numerous communications between the smaller branches of arteries, so that a connexion is established among them, and where the principal stream is arrested, as in the instance cited, the collateral branches above the stoppage enlarge, and transmit an increased quantity, most of which passes by the communicating channels into the branches beneath, which also enlarge, so as soon to re-establish a sufficient supply to the limb below, and this is effected in a short time. Immediately after the operation, the limb becomes cold and benumbed, but in a few days the circulation is again fully established by the new course just mentioned.

So also do we perceive that the blood-vessels accommodate themselves, one would almost think instinctively, to varying circumstances. Consider how the vessels of an impregnated womb not only adapt themselves to the increased wants of the enlarged womb itself, but furnish materials for the developement of the young that it bears. Observe how in due season the blood is determined to the breasts in increased quantity, and the vessels take on a new action, so as to furnish an abundant supply of rich and nutritious fluid, admirably adapted to the digestive powers of the new-born offspring. The annual and rapid developement of the stag's horns is another striking example that the blood-vessels are not passive tubes; and, in like manner, might be brought forward abundant evidence from comparative anatomy, from various diseased conditions, and from the modifications which the circulation undergoes, so as to be suited to each part of the body, according to the tissue of which it is composed, and the office which it has to perform.

When, by the contraction of the left ventricle, the blood is injected into the aorta, the three semilunar valves are immediately raised, so as completely to resist its return. Besides the impetus communicated to it by the force of the left ventricle, it is exposed to the grasp of the arterial tension: it therefore rushes forwards along the arteries. In an instant a new wave succeeds, for ventricles propel the blood from sixty to eighty times in a minute. In a healthy adult wave thus succeeds wave from the centre to the furthest extremities, and only becomes exhausted in the ultimate capillary branches.

It has been stated that the smaller arterial divisions possess a thicker, more elastic, and contractile middle coat than the larger trunks; they are also furnished more abundantly with blood, for it is to be observed that although the blood-vessels are the channels of the blood, yet they themselves require to have still smaller branches distributed upon their coats. Although even the larger trunks are not perhaps altogether passive agents, exerting merely a mechanical effect upon the blood, in virtue of their elasticity, yet they are not endowed with the same degree of irritability and vital contractility that the capillaries possess. The reason of this is partly that while the trunks are subservient to the general distribution, the smaller branches, and more particularly the capillaries, have to adapt themselves to the peculiar exigencies and conditions of the parts to which they more immediately dispense it.

It has been stated that it is only the larger trunks which require to be secured in a surgical operation; that the smaller branches so contract as to prevent the escape of the blood. This does not arise from the circumstance of the smaller column of blood which they transmit, for the tension will be in the same proportion on all the columns, of whatever size, but from the circumstance of their having proportionally a greater contractile power. Thus endowed, they readily adapt themselves to the conditions of the various parts of the system; a muscle in action requires a greater quantity of blood, and receives it; a gland is excited, and the materials are at hand from which its secretion is derived; an increased quantity of blood flows to one organ, the capillaries adapt themselves to the increase, as they do in other parts to the diminution necessarily occurring from such determination. It is in the capillaries that all the phenomena of growth and nutrition take place, all the secretions are elaborated, and all the various tissues formed. To venture upon a rude comparison, the heart and larger vessels are no further concerned in the various actions of the capillaries than the reservoir and hydraulic apparatus of a water company in a large city are with the water they transmit to the manufactories, shops, and domestic abodes of the consumers.

The arterial capillaries having supplied the various demands made upon the blood, form connexions with the venous capillaries, and transfer to them their contents. Here the opposite change to that which is effected in pulmonic capillaries takes place, and the blood changes from bright scarlet to dark purple. We have seen that after the blood leaves the left ventricle, it flows in the arteries from trunks to branches; but at this point, that is, at the commencement of the veins, it begins to flow from branches to trunks, and continues to do so till it again reaches the heart. The veins have the same number of coats as the arteries, but their walls are much thinner, their middle coat in particular; hence they are less elastic, possess little contractility, and a subordinate degree of vitality. They are larger, more numerous, and collectively of much greater capacity than the arteries. Excepting in the cavities and parts beyond the control of the will, they are furnished with valves, which are formed by a doubling of the inner coat, producing a little pouch. Sometimes the valves are single, but generally in pairs, and rarely treble; they readily permit the blood to flow towards the heart, but effectually prevent its retrograde course. In their substance and mode of action, they are similar to those of the pulmonary artery and aorta, already described. They may readily be seen in the arm of the living body, provided it be not loaded with too much fat. When a ribbon is tied round the arm, as is done in bloodletting, the veins swell, and become gorged with blood. On attempting to force the blood back towards the hand, little knots are seen to rise here and there, which resist its returning. These are the valves. But stroke the arm upwards, and the blood will flow without impediment. It was mentioned that the semilunar valves of the arteries act in the dead body: so do the valves of the veins; for, like them, their action depends entirely on their mechanical contrivance. For this reason, the anatomist, when he wishes to fill the veins with an injection, so that he may more readily trace them, and obtain a preparation worthy of a place in his museum, has to seek out the distant branches, and direct his injection towards the heart. If it be an arm or a leg that he wishes to prepare, he must find some vein on the hand or foot into which he may introduce his pipe, so as to throw his injection upwards. This is the reason why, in anatomical collections, the veins of those parts of the body furnished with valves are never minutely injected. The veins of the organs contained in the cavities, over the actions of which we possess no voluntary power, do not require valves, and consequently have none, the circulation in them proceeding in an uniform and regular manner, and subject to no impediment or interruption. But in those parts which are placed under the control of our will, and which we employ in so many different ways, and place in such a variety of conditions which impede the regular course of the blood through them, and would soon render them unfit for our use, they are furnished with these little valves, in number and proportion suited to the occasion.

The limbs are furnished with two sets of veins, one set lying immediately under the skin, the other deep seated, and accompanying the arteries. In the exercise of these organs, and consequently when the muscles are called into action, the circulation is carried on with greater vivacity. When the limbs are benumbed with cold, we have recourse to exercise to excite the languid circulation; the veins, however, not possessing the same irritability and vital contractility as the arteries, are not so readily roused; the blood would not therefore be carried off sufficiently rapidly were they not more numerous, and of greater capacity than the arteries. Further, during the exercise of our limbs, the blood does not so readily flow in the deep seated parts, for the play of the muscles interferes with the current; but then there are superficial channels along which it can pass with less impediment. Hence the surgeon, in bleeding a patient, directs him to move his fingers and grasp some object, that the blood may be driven along the superficial channel from whence the blood is flowing. It is chiefly the smaller arteries which establish connexions with each other, but the veins have free and numerous communications even in their larger trunks, as may readily be seen on the back of the hand, or on the fore-arm. Since veins are much more liable to have their currents interrupted, when one course is obstructed, another is thus ready to transmit the blood onwards.

At length the blood, collected from every part of the body, and conveyed by the veins, is poured into the right auricle of the heart, from whence we started with our description; and from the facts which have come under our consideration, can we arrive at any other conclusion than Harvey did,—shall we not admit that such must be the circulation of the blood? The two auriculo-ventricular valves, and the perfect and prompt effect of the valves of the pulmonary artery, aorta, and veins, even in the dead body, permit us to arrive at no other conclusion. If such as we have described be the true course which the blood pursues, then must every circumstance which tends to interfere with that course furnish a more or less clear evidence of its truth. It is unnecessary, then, to multiply evidence, by referring to the different effects produced by tying arteries and veins, the former swelling between the heart and the ligature, and the latter beyond the ligature; or to wounds of an artery, or of a vein, where the former is observed to bleed from the orifice next to the heart, the latter from that farthest from it. Nor need we advert to what has been noticed under the microscope on opening live animals, nor to the results of disease, since no indubitable fact has been brought to witness against the Harveian doctrine. There is, however, an operation which is sometimes brought forward as a proof, which may be here adverted to, on account of the curious circumstances connected with it, and the wild and absurd expectations that were entertained when it was first promulgated, namely, the operation of transfusion, in which the blood is taken from the vessels of one animal and transferred to those of another. It was suggested about the middle of the seventeenth century, when hopes were not entirely abolished respecting the elixir vitæ, which was to cure all diseases, and lengthen life to an indefinite extent, and when, too, it was the prevailing doctrine in the schools of medicine, that disease chiefly depended on morbid conditions of the blood and humours. The idea of changing the blood was therefore greedily seized upon. The diseased blood was to be withdrawn, and healthy blood substituted in its place. That of the young and vigorous was to fill the vessels of the old and decrepit; the peccant humours were to be withdrawn; such as gave origin to jaundiced jealousy, ill-natured spleen, and moping melancholy, were to be replaced by blood which might furnish more laudable secretions. So far did they carry their extravagances, that they transfused into human veins the blood of calves and sheep. As might have been expected, their hopes and expectations were disappointed, and not a few fatal results were the consequence. But, after all, were they a whit more extravagant, credulous, or stupid than those of our own day, who entrust their health and their lives to the St. John Longs, the homœopathists, and the advertising quacks who flourish among us. Although an operation which, from the way in which it was abused on its introduction at first, can only fill our minds with horror, contempt, and disgust, yet in later times, in the hands of the scientific, it has furnished curious illustrations of some of the vital functions, and has even preserved life when aid could be obtained from no other source. It has been ascertained that blood may be conveyed from one animal into the vessels of those of another of the same species, as from one dog into another dog, without proving fatal to that into which it is transfused, and thus place it in a condition of complete plethora throughout the whole vascular system, therefore furnishing an evidence for the truth of the circulation; but if the blood of an animal of a different species be introduced, it acts as a poison, shewing that the blood varies according to the animal. As a remedial measure, it has preserved life when endangered from hæmorrhage; and lately, when the devastating cholera was with us, warm water, with the salts found in the blood dissolved in it, was injected into the blood-vessels to the extent of pints in quantity, in order to compensate for the inordinate evacuation of the thinner part of the blood, and frequently with surprising temporary beneficial results; but experience soon shewed that little permanent benefit was to be expected.

The heart is one of those muscles over which we possess no immediate control. It is only part of our frame which is entrusted to our voluntary use. Whatever organs contribute more immediately to life, and the suspension of whose functions, even for an instant, would put a stop to the working of the machinery of our bodies, and ultimately destroy animation altogether, have been gifted by the benevolent Creator, with the power of continuing their action during the whole course of our corporeal existence. The nerves which are distributed to the organs which circulate the blood belong to a peculiar class, to which our attention will be directed in the proper place. Were we to estimate the value and importance of objects by their bulk, we should be inclined to suppose that the nerves of the heart are very insignificant. They are exceedingly minute, and can only be traced by the patient perseverance of those who are dexterous in such pursuits. Yet it is through these delicate hair-like threads that this organ is brought into association with many others with which it is known so directly to sympathize.

Whatever may be our particular views, it is admitted that the brain is the more immediate link between our corporeal frame and our intellectual conceptions, emotions, and passions; and how directly the heart sympathizes with the brain under these conditions is known to every one. It is chiefly when under the influence of the passions and emotions of the mind that we feel we have a heart. Under the influence of the more stormy passions, it is roused to violent exertion, so as to propel the blood into the sanguiferous tubes with redoubled force, while under those of a depressing kind its contractions become vacillating, feeble, and trembling. In the former instance, the blood rushes to the brain; and adding fuel to the flame, it infuses energy into the muscles; deeds of daring are done, and feats of strength accomplished, which, in cooler moments, could neither have been contemplated nor accomplished. In the latter case, from the irregular supply of blood, the mind becomes wavering and irresolute, and the muscles weak and debilitated, making a coward of one capable of the boldest determination, and a trembling poltroon of another with the limbs and sinews of a Hercules. From this we may learn how important, even for the sake of our bodies, it is that our passions should be kept in proper subjection, and how a well-regulated mind conduces to health and long life.

With the lungs, the organs of digestion, and indeed all the important organs of the system, the heart is intimately associated by sympathy. Then, in disease how many sympathies are developed, which in health are overlooked. It is well known that a change upon the organs of circulation is one of the most frequent concomitants of disease; so much so, that the medical practitioner, perhaps more intent upon matters of importance than routine, would be considered as careless and inattentive were he to neglect to feel the pulse, no matter what disease the patient was labouring under.

Though the heart is thus easily roused by the various sympathetic cords with which it is connected, yet, in the healthy state, it is possessed of little or no feeling, insomuch that it may be touched without any sensation being communicated to the individual to whom it belongs. A patient of the great Harvey had the heart exposed by a wound in the chest, so that it could be touched, and yet the patient was unaware of its being so, unless he kept his eye upon him who tried the experiment. The fact coming to the knowledge of Charles I, he accompanied Harvey, that he might have personal evidence of the fact.

The blood propelled from the left side of the heart does not return to the right in equal periods of time, for the extent of the circuits which it makes are as various as are the distances to which it is sent. The first arteries given off from the aorta, it has been mentioned, distribute their blood to the substance of the heart itself, which is soon returned to the right auricle by the vein, while the vessels which transmit and return the blood to the extremities of the body have an extended course before they complete the circuit. The nearer, therefore, any organ is to the heart, and the more immediately it receives its blood from it, the more is it under its control and influence, and the greater energy does it possess. In old age, or at the point of death, when the powers of the system are impaired and almost exhausted, the extremities of the body are the first to suffer, and thus become cold and benumbed. In the living body the circulation already begun has only to be continued. The blood-vessels are already full, all the communications are open, the blood is flowing in its customary channels. In these circumstances, the heart meets with comparatively little resistance, and hence the impulse which it gives to the blood is instantly felt through all the larger arterial ramifications, and even extends to their ultimate subdivisions, though the force of the impulse in the smaller branches is so much diffused, and the effects so minute, as to elude the touch or the eye; but in cases of morbid sensibility, as in toothache or a whitlow, by an internal feeling we are made as conscious of it as by feeling the pulse at the wrist.

The quantity of blood propelled into the aorta at each contraction of the left ventricle is estimated to be about two ounces, and as the auricles are filled when the ventricles are emptied, and conversely, four ounces will be the quantity in the heart at any given time,—a very small portion of the whole blood in the system. The diameter of the aorta is much smaller than the arterial branches collectively, and the whole arterial system is of much narrower capacity than that of the venous. The blood, therefore, from the time it leaves the left ventricle of the heart till it reaches the veins, is flowing from narrower into wider channels, and consequently its velocity and force will be diminished. As the veins begin to collect themselves into trunks of smaller diameter than the branches collectively, so will the current be again increased as it approaches the heart, though not to any considerable extent, from the free entrance it meets with into the right auricle. The heart, in proportion to the rest of the sanguiferous system and the body in general, varies in different animals. It is larger and more powerful in courageous animals than in the timid, in those that are prompt and agile in their movements than in those that are slow and torpid. It varies also in the proportion of its size and strength in different individuals of the same species; but in man, so many moral principles, from prejudice, education, and other causes, modify its action, that it would be as safe a rule to draw conclusions from the size and vigour of the limbs as to the courage or cowardice of an individual, as it would be from the relative size of the heart.

In youth the heart and arteries possess and exert a preponderating influence over the venous system. The earlier in life, the greater is this preponderance, so that the growth of the body at first is rapid, and gradually becomes slower, until it has reached its full developement. During maturity a balance is established between the two systems; whereas there is a preponderance of the one or the other at the beginning or at the close. In old age the power of the heart is much diminished, the arteries become more rigid, many of the smaller tubes are obliterated, and the blood is no longer propelled with that vigorous impulse which duly sustained its course through the capillaries. The body begins to waste, the skin becomes dry and relaxed, the hair is whitened or falls off, the eyes become hollow and dim, the limbs tremble, and the secretions are diminished. At the same time, blood accumulates in the venous system, and slowly and languidly returns to the heart; so that through the very means by which the body was built up in youth, and sustained with vigour in middle life, does it become decrepit and exhausted in old age, declaring to us, in language that cannot be mistaken, that here we have no abiding place, that sooner or later this body must crumble into dust, and be resolved into the elements from which it is formed.

The quantity of blood transmitted to an organ varies according to the tissue of which it is composed, and the function which it has to perform. The glands which have to furnish the secretions and muscles by which the various motions are effected, require an abundant supply, while bones, cartilages, tendons, and ligaments receive only a small quantity, and that by vessels so minute that they exclude the red colouring-matter of the blood.

Besides the modifications to which the circulation of blood through an organ is subjected by the number and size of the vessels distributed through it, there are other circumstances deserving attention, which, by their mechanical contrivance, are calculated to influence the force and velocity of the blood in a part. There are, we conceive, five modifications of arterial distribution worthy of particular notice: namely, the angle at which a branch arises from the trunk; the length and subdivision of the artery; its direction; its union; and lastly, the formation of a net-work. We shall make a few observations with respect to each of these.

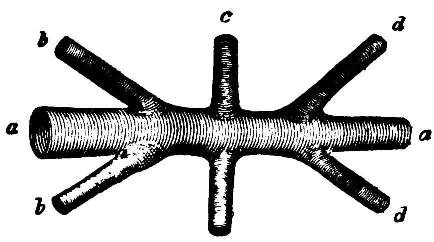

FIG. 2.

1*st*, As to the angle. It will readily be seen, on examining our cut, that the branches *b b*, arising from the trunk *a a*, pass off at an acute angle, *c c* at a right angle, and *d d* at an obtuse angle. The blood, to pass into *b b* must make a very considerable turn, and thus have its momentum diminished; in *c c* the turn is less, and still less in *d d*; so that if these vessels are of the same size, and distributed upon parts of the same structure and function, those supplied from *b b* will receive it with a smaller force and velocity than those supplied by *d d*. The conditions under which they act are therefore not equal. There is a beautiful example of this kind of distribution in the vessels given off from the aorta to supply the walls of the chest. At the commencement of the aorta the blood rushes along with the full impulse communicated by the heart; but that impulse is gradually diminished. Now, if we examine the arteries named intercostal, which supply the spaces between the ribs, particularly in an animal with a long back, such as the tiger, we shall find that the first arise by an acute, the middle by a right, and the lower ones by an obtuse angle, so that the angle may compensate for the difference of velocity and force, according to the part from which it takes its origin. By this beautiful contrivance the blood is distributed uniformly to all those parts which have the same office to execute.

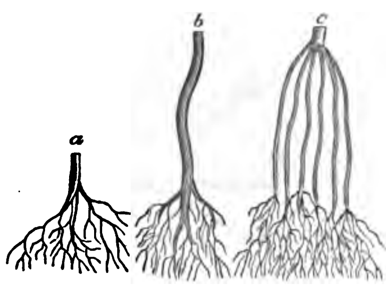

Fig. 3.

2*dly*, As to its length and subdivision of the artery. Suppose, as represented in the cut, *a*, *b*, and *c* are three vessels of equal capacity, and the blood propelled into them with equal force. *a* runs a short course, and divides into branches, which soon reach their destination; *b* is of great length before it divides, but its branches soon reach their destination; while *c* soon divides into branches, which, however, have to run far before they reach their destination. As the momentum of the blood is diminished by the friction on the sides of the vessels, it will be evident that in *a* it will be exposed to less diminution than in *b*, and in *b* than in *c*, so that the circulation will be much more retarded in *c* than in *a*, for two reasons, the length of course, and the subdivisions. Animals capable of rapid motions have a rapid circulation, and the arteries are so distributed as to insure it, as in *a*; while animals slow in their movements have the arteries which are distributed upon the muscles of this slow contraction, with a distribution after the manner of *c*. In the sloth, the main artery does not run down the extremities in one trunk, as it generally does, but is subdivided into numerous long branches. In the hedgehog the vessels which supply the muscles commanding the movements of its spine-armed skin are exceedingly long. They are also very long in the intestines of the pig. Now, in all these instances, the slow motions are confined to the parts which have this peculiarity of distribution. Though the sloth moves its limbs slowly, and with apparent pain and difficulty, the motions of its neck and jaws are rapid and prompt. There is another circumstance deserving notice, where muscular movements are very rapid, they quickly alternate with relaxation, and cannot continue in the state of contraction for any length of time; while in the instances referred to, they are capable of remaining in that state for a very considerable period, so that nothing could have been so well adapted to the conditions of the animals referred to.

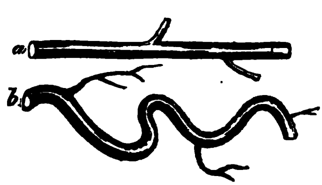

FIG. 4.

3*dly*, Direction. It is evident if *a* and *b* are of equal diameter and length, and if a fluid were propelled into both with the same force, in consequence of the serpentine course of *b*, it will meet with a much greater degree of resistance, and have its force diminished accordingly. Now, arteries are frequently thus serpentine, and even an artery nearly straight will become serpentine, if forcibly injected, presenting a beautiful provision in order to diminish force under particular and accidental circumstances. This serpentine course obtains in the arteries which enter the skull for the supply of the brain. In the horse it is more contorted than in the human subject, and he requires it to be so, particularly when feeding in the fields with his head in the dependent posture. Many other examples might be cited, but the effect and the advantages of such a distribution must be sufficiently obvious.

4th, Union. The cut represents two branches, *a a*, uniting to form a third, somewhat larger than either. Of this we have an example in two of the vessels which enter to supply the brain. If the trunk be of greater capacity than the separate branches, then the velocity will be diminished; but if the converse, it will be accelerated. Another effect will be produced,—the pulsative motion in the direction of the dotted arrows *a a*, when the streams meet, will be reduced to continuous motion in the direction of the arrow *b*. By a similar contrivance, the interrupted impulse with which the water is forced in the working of the fire-engine, issues as a continued stream from the pipe with which the water is played.

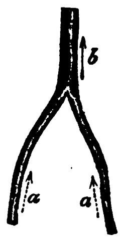

FIG. 5.

Lastly, Net-work. There are several examples of this kind of modification in different animals, where an artery is broken up into a great many branches which form numerous communications with each other, so as to constitute an exceedingly involved and intricate net-work. There are two modifications; 1*st*, where, as in Fig. 6, the artery, *a*, is broken up to form the net-work *b*, the branches of which are reunited into one trunk, *c*.

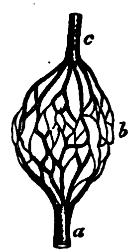

FIG. 6.

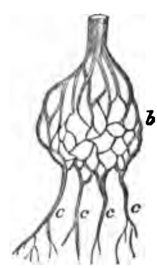

FIG. 7.

2dly, as in Fig. 7, where the vessels of the net-work, *b*, instead of uniting to re-form one trunk, form several, *c c c c*. Now, it will be evident that when the main stream is thus broken up, the force must be very much diffused and diminished, and the pulsative jet must also be even more effectually destroyed than in the fourth modification of union. There is a net-work in the principal artery which supplies the brain, as in Fig. 6, in ruminating animals, which, in browsing, are able to keep their heads for a long time in the dependent posture without sanguineous congestion, or any risk of apoplexy. Here we have even a more perfect preventive of the evils which might otherwise have arisen from the head being long kept in the dependent position than in the horse already alluded to in the third modification. The formation of the plexus, according to Fig. 7, is found in the arteries of the intestines of the pig, and the inferences which may be drawn from it will be considered when we treat of the peculiarities of circulation in the abdomen. Such are among the more striking mechanical modifications to which the circulation is subjected,—modifications which we conceive have not as yet received that attention to which they are entitled.

Besides the general laws which affect the distribution of the blood through the body, every different organ may be said to have a peculiar circulation of its own, either in respect to quantity, velocity, or other circumstances which adjust it to its own particular conditions. It would be out of place here to enter at any length into these considerations; but there are three situations in which the peculiarities are so striking and important, that they must not be overlooked. These are in the head, chest, and abdomen. In bringing these under discussion, we shall first treat of those of the chest.

Although the alternate contraction and expansion of the chest during breathing be chiefly intended for the functions exercised by the lungs, yet these two conditions affect, to no trifling extent, both the lesser and the larger circulation. With respect to the effects produced upon the circulation through the lungs by the increased quantity of air in the tubes and cells, the whole volume of the lungs is increased; the circulation through them is promoted; the right ventricle has less resistance to overcome in propelling the blood into the pulmonary artery; it flows with greater freedom through the arterial and venous capillaries, and returns more readily to the left ventricle. Thus, at the time when the greatest quantity of air is in the lungs, at that very time the greatest quantity of blood passes through them. In the opposite condition, when the lungs and other viscera sustain a certain degree of compression from the diminution of the capacity of the chest, the passage of the blood through the lungs is impeded. There is also not the same free entrance for it into the chest by the great veins, and a retardation of it in the whole venous system is the consequence. During ordinary respiration these effects are but momentary, and so slight as to escape notice, yet they may be beneficial by the alternate acceleration and retardation of the tide of blood through the body, inducing a certain degree of action and repose in the whole sanguiferous system.

In extraordinary cases, however, where respiration is impeded, interrupted, or imperfect, the effects become prominent, and the consequences important. Let any one take in a full breath and hold it, he will in a short time experience an uneasy sensation in the chest, the face will become suffused, and a painful feeling of distension will be experienced in the head, so as to compel him to put a stop to the experiment. Again, let him expel as much air as he can from the chest, and then hold the breath, he will find that in one half the time the uneasy sensation will be experienced, more particularly in the suffusion of the face, and the feeling of distension in the head. Thus it will be perceived that there is a freer passage of blood into the chest, and also through the lungs, in the former than in the latter condition; for these effects arise from the impediment to the blood in its return from the head and face, and to its transmission through the lungs. In straining, where the breath is retained after a full inspiration, and the muscles powerfully thrown into action, the organs in the chest are forcibly compressed, and the blood is impelled with increased force from that cavity. The same happens when we make any violent effort, as lifting a heavy load, where we take a full breath, and retain it, so as to increase the power of the muscles. In these cases wounds sometimes break out afresh, and vessels are occasionally ruptured. This may happen in the vessels of the brain, and the person fall down in a fatal apoplexy. In loud and forcible speaking, or in singing, as on the stage, there is for similar reasons an impediment to the return of the blood into the chest; the face becomes suffused, and the veins in the neck and throat swell. In asthma, hooping-cough, croup, &c. the influence of the respiratory movements on the circulation of the blood is strongly displayed; and at the point of death, when the breathing becomes weak and interrupted, the veins of the neck will be observed to swell and subside in accordance with the movements of the chest—to subside during inspiration, and swell during expiration. In all these instances the influence is extended to the circulation through the skull, and will be better understood when we have explained the peculiarities of the distribution of blood through that cavity.

In the care bestowed for the protection of the brain from external injury, by the curiously constructed case in which it is contained, we have an evidence of its importance in the animal economy. Soft and delicate in its texture—easily deranged in function—requiring a large supply, but impatient of superfluous accumulation of blood, there are many curious contrivances to insure the necessary quantity without endangering its structure or disturbing its function. There are four arteries which transmit blood to the brain: the two larger internal carotids, and the two smaller vertebrals. It is returned by two veins: the internal jugulars. It has been stated that the arteries, on entering the skull, make a tortuous and indirect entrance, so as to diminish the impetus of the blood; and that this is more particularly the case in some of the lower animals, as the horse. In man, from the usual position of the body when awake and in a state of activity, the blood has to be propelled upwards, contrary to the influence of gravity, and therefore the serpentine direction to an equal extent is not required in him. The effect of position upon the circulation through the head must be well known to every one who has laboured under headache, who will recollect how much the pain is aggravated by stooping. This may, however, partly arise from obstruction to the return by the veins, as well as from the increased flow by the arteries.

In entering the skull, the carotids pass close to the internal ear, so that on increased sensibility of that organ, or inordinate excitement of the arterial pulsation, their throbbing can be distinctly heard. So soon as the four arteries have entered, the two vertebrals are formed into one, as has been mentioned; besides, there is a free communication established with each other by all the four. They then begin to divide into branches, which do not however enter immediately into the delicate nervous substance of the brain, but are first minutely subdivided upon a membrane which closely embraces its surface, and enters between its folds. So minutely are these vessels ramified before they penetrate into the nervous matter, that few are capable of transmitting the red globules of the blood; though the larger branches freely communicate before they subdivide, yet they appear to form few connections in their smaller branches. If any of the four trunks be obstructed, or if one of them be tied, as is sometimes the case, by the surgeon, in consequence of the connection among them, the blood is not cut off from the branches of that which is obstructed. There is another circumstance which characterizes the arteries of the brain: their coats are much thinner and more delicate than in any other organ, for the strength and thickness of the coats of arteries vary very much in different parts; those of the lower extremity, for example, are much thicker and tougher than in most other parts; but here they are more tender than any where else. Hence they are more apt to give way, producing a fatal effusion of blood.

The brain in the living body, and after death, so long as it retains its vital warmth, is much softer than when it becomes cold. It undergoes a kind of coagulation after death, whereby it becomes firmer, until decomposition commences. In the living state it may be said to be semifluid, and hence probably the necessity for the delicacy of the coats of its blood vessels. The veins returning the blood are at first distributed also upon the membrane. They never accumulate into large branches, but instead of doing so, they pour their contents into receptacles for the purpose, termed sinuses, to which we shall immediately refer. In most parts of the body the larger veins accompany the larger arteries, but here that is not the case; for whereas the arteries divide from the base towards the vertex, the veins collect their branches from the base, and form larger at the vertex, where they enter the sinuses. Another circumstance influencing the circulation in the brain is the effect of the strong unyielding vault of the skull in which it is contained, whereby the absolute quantity of blood is at all times the same, the atmospheric pressure supporting it, even independently of the vascular action on the one hand, and the vault of the skull preventing the vicissitudes of atmospheric pressure on the other. It has been ascertained that if an animal be bled to death, there will yet remain as much blood in the skull as if it had been killed without shedding a drop of blood. But if a portion of the skull be sawn out, and an opening made through the dense membrane which lines it, and the animal then bled to death, the vessels of the brain will in this case be found as much blanched as those of any other part of the body, in consequence of the atmospheric pressure having now had an opportunity of exerting its influence upon them.

Although, then, we may diminish the force and the velocity with which the blood circulates through the brain, we cannot diminish the quantity,—we mean in the whole cavity. That there may be a loss of balance is true: that is to say, it may be determined to, or congested in particular parts. Veins are liable to accumulation of blood from the nature of their coats. Such accumulations are, however, incompatible with the office and safety of the brain, and therefore, to prevent the risk of such an occurrence, the veins of the brain are not suffered to collect themselves into trunks, but pour their contents into the sinuses. These are placed in the folds of the dense unyielding membrane which lines the skull or *dura mater*, so that the venous blood in any considerable quantity can only accumulate in these receptacles, which, from their strength, resist distension, and have, even in their interior, transverse bands, named Willis' cords, which further act towards the same end. The manner in which the veins enter is also worthy of remark. The current of the blood in the sinus is in the direction of the arrows *a a*, that is, from before backwards, while in the veins it is in the direction of the arrows, *d d d*, from behind forwards. The reason is this: It has been already mentioned that when the chest is enlarged, as in inspiration, there is a freer passage for the blood into it, but that when it is contracted in expelling the air, there is an impediment to its entrance; that, therefore, the veins are seen occa-

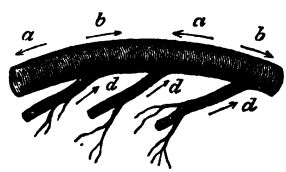

FIG. 8.

sionally to swell. From the right auricle, along the descending cava and internal jugular vein, up to the sinus, there are frequently no valves, so that any impediment to the entrance of the blood into the chest or auricle causes a rise, while its free entrance produces a subsidence throughout the whole extent, or a flux and reflux, which is sometimes called venous pulsation. In laborious breathing, especially, this takes place. Now, if the reflux extended to the veins of the brain, it might, and most probably would, prove fatal; but as the reflux in the sinus will be in the direction of the arrows *b b*, coincident with the current in the veins, and of the arrows *d d d*, the obliquity of the entrance will therefore prevent the blood from re-entering the veins, though there will be an obstruction to their emptying themselves into the sinus, which explains what occurs under such circumstances as the following. When the brain is compressed, as from a fracture of the skull, and the depression of the fractured portion, the breathing becomes affected, it takes place at intervals, or is rendered stertorous. In the performance of the surgical operation required in such cases, the brain is seen to rise and fall—to rise during expiration, and subside during inspiration: that is, during expiration there is an impediment to the entrance of the blood into the sinus from the veins; it consequently accumulates in them, and the brain swells, but in inspiration the current of the blood becomes free, and the brain subsides. Thus we see in the transmission, in the distribution, in the collection and return of the blood to and from that noble and delicate organ the brain, everything is foreseen and provided for, nothing left to chance, overlooked, or omitted.

We have next to turn our attention to the peculiarities to be found in the circulation of the blood through the abdomen. That cavity is chiefly occupied by the organs which are either directly or indirectly engaged in the preparation of the food for its entrance into the living vessels, and for the introduction of fluids to compensate for the loss every moment sustained by the general circulating mass.

The motion to which the viscera of the abdomen are constantly exposed, in consequence of the respiratory movements, undoubtedly has an effect in promoting the circulation through them. The stomach and intestinal canal have a muscular coat which produces a peculiar motion hereafter to be described. This is altogether independent of the will, and in a state of health we are unconscious of its existence. This motion is slow and uniform, varying in these respects according to the habit of the individual, and other circumstances. The circulation through the stomach, intestinal tube, spleen, pancreas, and certain folds of the lining membrane of the abdomen, is different from that of any other part of the body. The blood is, as elsewhere, transmitted by arteries; as elsewhere, it is collected by veins; but instead of directly conveying it to the heart, these collect themselves into one trunk, which proceeds to the liver; there it again divides through the substance of that organ, after the manner of an artery, that is, distributing the blood from trunks to branches. Again it is taken

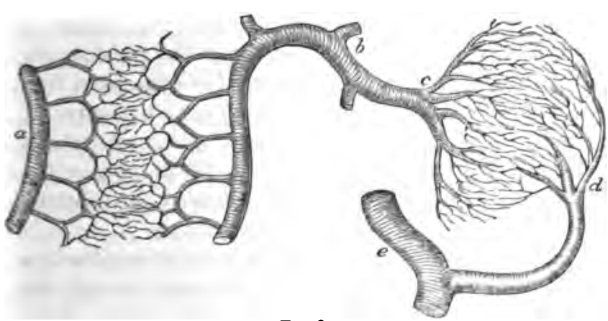

FIG. 9.

up by veins, which are collected into one or more trunks; and these pour into it the ascending cava to be carried into the right auricle. Thus we have it, 1*st.* from trunks to branches of the artery; 2*dly*, from the branches to the trunk of a vein; 3*dly*, from the trunk of that vein, by its branches sent to the liver; and, *lastly*, taken up by veins, and conveyed to the cava. Our cut will illustrate this, where *a* is intended for the mesenteric artery, *b* the porta of the abdomen collecting the blood from the viscera, *c* the porta of the liver distributing it through that viscus, *d* the cava of the liver conveying it into the ascending cava *e*. In this way the course of the blood is much lengthened, and from the greater portion being in veins, it must be comparatively sluggish. The first and second set of veins are collectively termed the porta or vena portæ, or the vein of the gate,—a name given by the ancients from its entering under a portion of the liver which they called the gate. That portion which takes up the blood from the extremities of the arteries is termed the porta of the abdomen; the other, which transmits it through the liver, is called the porta of the liver, and the vein by which it is collected from the liver is called the cava of the liver.

The mode of ramification of the arteries of the intestinal canal deserves notice. In the human subject it divides into primary branches, which establish very free communications with each other, forming what are termed arches; from the convexities of these arches other secondary branches are sent off, which in a similar manner form arches, and so on till they reach the intestine, forming generally three or four series of arches before they do so, and constituting the best example we have in the human body of the net-work, which was stated as being calculated to diminish the force and velocity of the blood, and also take off the pulsative movement. Thus the blood will flow to the intestines in a tranquil uniform stream, adapted to the slow continuous motion of the intestine. Moreover, had the blood been propelled rapidly along these arteries, how could such rapid movement accord with what must necessarily be a very slow, languid, and sluggish stream in the venous system beyond? In carnivorous animals, which have quick digestion, the arches are not so numerous, nor the communications so free; while in herbivorous animals they are more frequent than in the human species. In the pig both arteries and veins present a very remarkable distribution: they are closely and most intricately interwoven, so as to present one of the most remarkable examples of vascular arrangement in the whole animal kingdom. The adjustment of this peculiar abdominal circulation to the condition of the different organs will be further considered when we come to digestion.

Having now brought under our consideration the general structure and mode of action of the different organs engaged in the distribution of the blood through the body; having adverted to certain mechanical conditions to which they are subjected, and the principal modifications they undergo, so as to adapt them to particular organs and conditions, our attention is next to be directed to the function of respiration, which, in one point of view, may be considered as subsidiary to circulation, in so far as one of its most important offices is to prepare the blood while passing through the lesser circulation for its subsequent course through the greater.

CHAPTER II.

RESPIRATION.

Organs of Inspiration—Expiration—Passages through the Diaphragm—Incidental Respiration—Respiration in Birds—in Reptiles—Opinions of the Ancients as to the use of Respiration—Atmosphere—Its Height—Weight—Humidity—Temperature—Composition—Changes produced on the Air by breathing—Quantity of Water thrown off in the Breath—Diminution of Oxygen—Increase of Carbonic Acid—State of Nitrogen—Changes upon the Blood—In Colour—Density—Chemical Constitution—Temperature and Animal Heat—Source and Distribution of—How regulated when the Body is exposed to High and to Low Temperatures—Progressive Developement of Animal Heat in the New-born—Adaptation to the Temperature of different Climates—Hybernation—Voice and Speech—Respiration of different Gases—Asphyxia—Means for restoring the Functions in Suspended Animation.

Respiration is that function in living bodies by which the circulating fluids are brought under the influence of the atmospheric air, during which the fluid exposed to the air, and the air itself, mutually act on each other. The organs engaged in this function present great diversities, according to the rank the individual holds in the organic kingdom. In man, mammalia, and birds, respiration is performed by the lungs, and the alternate enlargement and diminution of the cavity in which they are contained. In reptiles the air is forced down, not drawn into the lungs. In fishes the gills perform this office. Animals still lower in the scale present various modes in which it is performed; and in plants the leaves are its principal agents. We shall chiefly confine ourselves to the consideration of this function as it obtains in man, though for the purpose of illustration other animals will be occasionally referred to.

The organs engaged in respiration are the direct and the accessary; the lungs being the former, the organs by which the air is introduced into the lungs constituting the latter. The chest or thorax is of the form of a cone, with the apex cut off, approaching in the human subject, and particularly in the male, to a quadrangular pyramid. The skeleton of its walls is composed of twelve vertebræ, twelve ribs on each side, with their cartilages, and the breast-bone in front. It is separated from the cavity of the abdomen by a muscular partition called the diaphragm. The vertebræ are termed dorsal, to distinguish them from seven of the neck and five of the loins, which together form the flexible spine. These dorsal vertebræ are so united or hinged together as to permit of a less degree of motion than those of either the neck or loins. The ribs are of an arched form, the first forming the segment of the smallest circle, the circle gradually enlarging downwards. Their upper margin is rounded, and has an inclination inwards; the lower is sharp, and inclines outwards. At their attachment behind to the vertebræ they incline from above downwards and forwards. From these circumstances, when they are raised, the chest is enlarged. Excepting the two last, they have two points of connection with the vertebræ behind. When they come forwards, they terminate in cartilages or gristle, by which they are connected to the breast-bone or to each other, excepting the last two, which float loosely. Anteriorly, from the first downwards, the cartilages become gradually longer, more slender, and flexible. From the connection behind, and from the termination in front, the upper rib is always more fixed than that immediately beneath it. These points, along with the segment of the circle which they form enlarging downwards, we shall find have a considerable influence on their office.

There are two conditions of respiration which are necessary to be considered—ordinary and incidental. Ordinary respiration commences at birth, and must be carried on to the last; it is conducted whether we are asleep or awake. In so far, therefore, it is like the function of circulation, an involuntary act. But we possess a direct power over breathing which we have not over circulation. To a certain extent we can hurry or retard, or suspend it for some time, either when the chest is expanded or contracted, or expel the air with different degrees of force. This extraordinary or incidental respiration is employed in speaking, singing, laughing, crying, coughing, straining, &c. In both conditions respiration consists of two acts: inspiration, during which the chest is enlarged, and an additional portion of air drawn in; and expiration, when the chest is contracted and a portion of air expelled.

The chest is enlarged by the elevation of the ribs and descent of the diaphragm. By the former it is enlarged from before backwards, and from right to left; and by the latter from above downwards, so that it is thus enlarged in all its diameters. When the ribs are elevated, their points of connection behind are not so, and the seven superior, from being fixed anteriorly to the breast-bone, are elevated at neither extremity. From the form and position of the ribs, it is by the change of the plane of their inclination, when they are depressed or elevated, that they produce a difference in the capacity of the chest. In ordinary inspiration a set of muscles termed intercostals are the only ones required for the elevation of the ribs. These muscles present us with a very beautiful example of design and contrivance. They consist of two layers, lying one upon the other, their fibres running in different directions. The external layer begins behind at the vertebræ, and runs downwards and forwards from the inferior margin of the upper to the superior margin of the lower rib. This layer is not continued the whole length of the ribs, but ceases near the cartilages. The internal layer commences at the breast-bone, is attached as the last, but runs from above downwards and backwards, and ceases before it reaches the vertebræ.

To understand the manner in which these muscles act, it is necessary to bear in mind that the motions of the ribs are upwards and downwards on an axis, extending from the vertebral attachment behind to their attachment in front to the breast-bone; that at these points of attachment they are not elevated or depressed, but roll in the socket; as the rib immediately above is the segment of a smaller circle than that immediately below, a motive power extended between them has a greater purchase upon the lower than the upper. *2dly*, As already stated, the superior rib is more fixed than the inferior; and, *3dly*, we shall find that by the direction of the fibres of the intercostals, they possess a longer lever upon the rib below than on the rib above, and consequently, other things being equal, they move the lower to the upper faster than the upper to the lower; and as this takes place throughout the whole series, the general result is the elevation of the whole. This last position may be

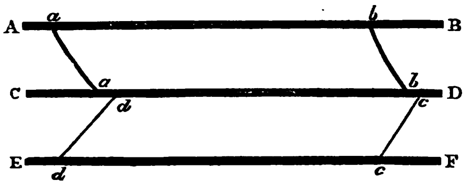

Fig. 10.

illustrated by reference to the figure. Suppose A B, C D, and E F, represent ribs moveable upon their two extremities, and A C E the posterior or vertebral extremities, and B D F the anterior: let *a a* and *b b* represent the muscular fibres of the external layer of the intercostals, it is evident that *a a* has a longer lever upon C D than A B; but if continued on to *b b*, the reverse would happen; *b b* would have a longer lever on A B than C D; but wherever this would take place, there the external intercostals cease. This also applies to the internal layer, which commences at the breast-bone in front, and terminates some space before it reaches the vertebræ; and for similar reasons as above, as will be seen by looking at the figure, where *c c* has a longer lever upon E F than C D, but would have the reverse were it continued on as at *d d*, which it is not, but ceases before it comes to have any such superior power over the rib above. Therefore, from the difference of the size of the circles of which the ribs form segments, from the greater mobility of the lower ribs, and from the fibres of both layers having a longer lever upon the rib below than the rib above, they elevate the ribs.

The transverse partition dividing the thorax from the abdomen, named the diaphragm, is usually described as composed of two portions; the fibres of the larger proceeding from their attachments to the cartilages of the lower ribs to a central heart-shaped or cordiform tendon. The lesser arises by two fleshy columns from the vertebræ of the loins to be inserted also into the tendinous centre; so that the diaphragm forms a dome, convex above, and concave below, with a central tendon; this tendon is attached to the capsule of the heart at its upper surface, whereby it is rendered more fixed than the fleshy circumference.

When the diaphragm is thrown into action, the fleshy fibres contract, push downwards the viscera of the abdomen, and enlarge the chest in the diameter from above downwards, and, along with the muscles of the walls of the abdomen, produce that alternate motion upwards and downwards, in accordance with respiratory movements observed in that cavity.

The curious and beautiful contrivance of the openings for the transmission of organs through this partition may be here adverted to, and particularly those for the aorta, the ascending cava, and the gullet. The inferior cava, in its ascent in the abdomen, as it approaches the liver, leaves the vertebral column, and is lodged in a depression of the liver, so as to be able to penetrate the diaphragm near its centre, towards the right of the tendon. On entering the chest, it immediately pours its blood into the right auricle. The veins collecting the blood from the walls of the abdomen could not, from this course of the cava, have reached it without being exposed to interruption. Instead of doing so, however, they form a vein which lies close upon the vertebræ, entering the chest by another opening, through which the aorta passes into the abdomen. This vein proceeds upwards on the right of the aorta, collecting the branches from the walls of the chest, and joins the descending cava. As it is a single vein, or without a fellow, it is called the azygos. The main trunk of the absorbents also passes through the opening for the aorta.

We have therefore to consider two passages in the diaphragm for blood-vessels—the anterior for the vena cava, the posterior for the aorta, vena azygos, and thoracic duct. In the different states of action and repose of the diaphragm, these might have been exposed to impediment, but this is completely obviated by the following contrivances. Tendons are not contractile, but are to be considered merely as mechanical cords regulated and moved by the fleshy fibres. The cordiform tendon of the diaphragm is formed by the crossing and curious interlacing of the tendinous fibres; and they are so arranged as to form an opening for the cava, which, in no state of the diaphragm is liable to be affected in any way, the interlacement of the tendinous fibres being such as to preserve the passage patent in every condition. The aortal opening is somewhat differently constructed, but the result is as complete. It is situated between the two columns of the diaphragm, which take tendinous origins from the vertebræ, some of the fibres of which cross and are interlaced, so as to form an arch over the passage. Both of these con-formations are perfectly adapted to the conditions required, that of a free passage at all times, whether the diaphragm be in a state of contraction or relaxation. The passage for the gullet, on the other hand, is through the fleshy portion of the diaphragm, consequently it becomes subject to obstruction in certain conditions of that muscle, as in hiccough, where a difficulty of deglutition is experienced. As deglutition, however, is only an occasional act, the diaphragm in ordinary cases offers no resistance to the transmission of the food, but rather co-operates with the gullet.

If a person attends for a little to what takes place in his own breathing, he will become conscious that inspiration is that which principally requires an effort in ordinary cases, and that the walls of the chest return to the state of expiration of their own accord, as if it were their more natural condition. Indeed, in healthy tranquil respiration, such is the mode in which the ribs are hinged to the vertebræ behind, and also the elasticity of their cartilages in front, that by these mechanical conditions alone the chest returns to the state of expiration, without the necessity of muscular intervention. Accordingly, when death takes place, this is the condition in which it is left. Hence the occurrence of death is announced by saying, that the person has expired. During sleep, or while we are at rest, this important function requires merely that the diaphragm, and two layers of intercostals be called into action sufficiently, so that the chest may be enlarged to the necessary extent; and to this extent their involuntary or instinctive contraction enables them uniformly to carry it, without weariness or fatigue, from the first inspiration at birth to the last expiration, when the breath of life is finally yielded up, however long may be the interval between.

Besides the above means for the constant, ordinary, or involuntary enlargement and diminution of the chest, so as to carry on the function of respiration, under various circumstances, the apparatus engaged in these offices are called into action at the command of the will, as in blowing, singing, &c.; or we instinctively employ them, as in laughing, crying, sighing, yawning, &c.; and besides, other muscles powerfully co-operate with the ordinary means in these and in other certain cases, so as to enlarge and diminish the cavity of the chest to the uttermost, as in coughing, speaking, straining; in all of which instances, many advantages result from the full exercise of this function, and without it indeed they could not have been performed.

When we take in a full breath, we elevate the shoulders by means of muscles extending from the head and neck, and become conscious of the exertion of an effort. In consequence of this elevation and fixation of the shoulders, several powerful muscles attached to the shoulder-blade and arm, connected with the ribs, obtain a fixed point of action, and have their levers also vastly increased. Five pairs of muscles are employed in elevating and fixing the shoulders, and unless they are called into play, those extending from the ribs to the shoulders would act under much disadvantage. We have only to try forcibly to draw in our breath without raising the shoulders, and then do so, at the sametime elevating them, to be convinced how much more air we can draw in, and how much more easily we effect it in the latter than in the former condition. For we hereby obtain the aid of at least four pairs of powerful muscles, which, as they cannot now pull down the shoulders, raise the ribs to them. In an instant, then, whether from the exertion of our will, or from an incidental occurrence calling forth the instinctive employment of the respiratory apparatus, these extraordinary means start into action in aid of the ordinary instruments engaged. There is no need on our part to consider the number that may be selected; no need for selection; no necessity for calculating the force, velocity, or extent to which it will be requisite to employ them. In the proper number, with adequate power, and in the necessary order of succession, are they ready to obey the behests of a Carib or a Hottentot as well as those of a Harvey or a Hunter.

It has been stated that the mechanical contrivance of the chest is such that little or no muscular interference is required for the expulsion of the proper quantity of air in ordinary respiration. But in other cases, muscular exertion becomes absolutely necessary, so as to expel it with different degrees of force, and otherwise to regulate it. Thus, in straining, the chest is filled, and its contents powerfully compressed. In singing, it is filled, and the air forced along the windpipe, through the organs of voice; its quantity, velocity, and force being adjusted with the greatest nicety, in accordance with the sound required to be produced.

There are four pairs of muscles which extend from the bones of the pelvis to the ribs and breast-bone, forming the anterior and lateral walls of the abdomen, constructed upon the most curious and admirable principles, which, however, we need not at present enter upon. These muscles, by their joint action, pull down the ribs; at the same time they press upwards, and somewhat backwards, the viscera against the relaxed diaphragm. Therefore, in consequence of the action of these muscles, the ribs and sternum are depressed, the diaphragm is pushed up, and the chest diminished in all its diameters, and this they are able to effect with the greatest nicety, to the necessary extent, or with the necessary velocity and force.

We have now to consider the structure of the lungs. We have already found that during each complete circulation, the whole mass of blood is transmitted through these organs by the ramifications of the pulmonary arteries and veins. Between the meshes of these vessels we have air tubes every where penetrating and conveying the atmospheric air. The windpipe will afterwards come more particularly under our consideration as an instrument of voice. At present it may be sufficient to state that at its upper part in the throat there is a complicated apparatus connected with it, termed the larynx, by which the entrance and exit of the air are regulated. The windpipe itself is composed of about eighteen cartilaginous rings, which are incomplete posteriorly, where it is in contact with the gullet. It thus forms a rigid tube, capable of resisting the pressure of the external air when that which it contains becomes rarefied. Had it not been capable of bearing a certain degree of pressure from the external air, its sides would have been liable to be compressed, and thus suffocation must have been the result. Thus we find in birds, where the air suffers a greater degree of rarefaction, and is also in greater proportional quantity in the body of the animal, the rings composing the windpipe are much firmer, indeed almost bony, and are complete round the whole circumference; while in reptiles, where the air is propelled downwards by a force from above, it is more yielding than even in man and mammalia.

On the entrance of the windpipe into the chest, it divides into two trunks, one proceeding to each side. These penetrate into the substance of the lungs, and immediately begin to give off branches, which, by reiterated subdivisions, become exceedingly minute, and permeate their whole substance, the ultimate extremities of these tubes terminating in very small cells. The smaller divisions of the air-tubes are devoid of cartilage, as, beyond the secondary branches of the windpipe, that substance becomes unnecessary. Throughout the whole extent of the air-passages they are lined by a mucous membrane, continuous with the lining membrane of the mouth, nostrils, and throat.

The essential substance or tissue of the lungs may be considered as consisting in a congeries of blood-vessels and air-vessels, the pulmonary arteries bringing to them the dark purple, and the pulmonary veins carrying off the bright scarlet-coloured blood, while the reciprocal action of the air and the blood on each other is the efficient agent of this change. A subordinate set of blood-vessels, termed bronchials, furnish them with nourishment and with blood for the mucus of the air-passages. The nerves are numerous, and belong to a particular class, to which we shall afterwards direct our attention. The substance of the lungs is light and spongy; from our first inspiration at the moment of birth, it contains always more or less aerial fluid, and is never exhausted by any expiration that afterwards succeeds. Surrounding the lungs there is a membrane covering the whole surface, and reflected upon the walls of the chest, so as to form a shut sac, into which a thin watery vapour is constantly exhaled to preserve the surfaces moist and slippery. To this the name of pleura is given: it constitutes the seat of the disease termed pleurisy.

A correct general notion of the lungs may be easily obtained by examining them in the sheep, rabbit, or other quadruped. In common language they are known by the name of lights. In mammalia they are generally divided into a greater or less number of lobes. In animals with a very flexible spine, as in the cat tribe, such as the tiger and leopard, the lobes are more numerous, and the divisions more complete than in those animals in which the spine is more rigid, so that the lungs may more readily adapt themselves to the various postures of the animals. The chest is divided into three principal compartments; the middle containing the heart, the two lateral the lungs. Between these there is no communication, so that if we throw air or any other fluid into one of these compartments, it does not find its way into the others. The lungs belong to the double organs of the body, like the eyes, the ears, &c., the windpipe and its appendages being common to both. Accordingly, one lung may be, and often is diseased, while the other remains healthy, and may alone carry on the function for many years.

We shall now proceed to consider the effect of the respiratory movements.

As the chest becomes enlarged, the pressure upon the viscera, and particularly upon the lungs, is diminished. The residual air left after the preceding expiration expands and dilates the cells and tubes, and thereby the whole volume of the lungs, so that they are always in contact with the inner surface of the walls of the chest. In consequence of the air having a constant tendency to keep up the equilibrium of pressure, where it becomes rarefied from any cause, the surrounding atmosphere rushes towards that part, in order to restore the equilibrium. If we exhaust the receiver of the air-pump, and then open the valve, the air will rush in, or if we heat our apartment, so as to rarefy its atmosphere, a draught will take place; or if we enlarge the receptacle in which air may be contained, so as to cause expansion, fresh air enters to keep up the balance, as in the common bellows.

The tubes and cells of the lungs being dilated, the external air enters by the windpipe in a quantity commensurate with the expansion. There is not at first a rarefaction to the full extent, and then a sudden admission of air, so as to produce anything like a rush; but as it becomes more and more rarefied, so does the external air enter coincident with the expansion. Although rarefaction of the air in the lungs be the efficient cause of fresh portions entering, yet so admirable is the adjustment, that the rarefaction is never suffered to take place to any appreciable extent. The reason is obvious: The air cells are formed of an exceedingly delicate membrane, incapable of bearing anything like sudden distension or pressure. The extreme branches of the blood vessels, too, distributed around the cells, would have been liable to rupture, so that the very first inspiration might have proved fatal. By the dilatation of the lungs, and the entrance of fresh air, the muscles are enabled to enlarge the chest to the full extent. Without this it is impossible to do so; for powerful as the muscles may be which are employed in inspiration, the most vigorous effort they are capable of exerting is totally inadequate to lift the ribs against the atmospheric pressure, if air be prevented from entering the chest. If any one try complete expiration, then hold the breath, and endeavour to elevate the ribs, he will find that it is impossible to do so to any extent.

In the act of inspiration, then, the following is the succession of the phenomena which occur: enlargement of the chest by means of the muscles; rarefaction of the residual air, and consequent expansion of the cells; entrance of a fresh portion of air to preserve the balance. As the chest contracts during expiration, the lungs now become subject to pressure, so that a portion of the contents of the cells is forced along the tubes, and expelled through the windpipe. So far as the entrance and exit of the air are concerned, the lungs, from the above description, are altogether passive; but the agents employed are fully adequate to the effect required, so that a sufficient renewal of air is at all times perfectly insured.

In man and mammalia the windpipe, as we have stated, is divided into numerous branches, which become more and more minute, and ultimately terminate in very small cells. The surface with which the air comes in contact is thus vastly extended, and has been estimated by the celebrated Haller as equal to fifteen times that of the whole external surface of the body. The blood being also exposed to this surface, the reciprocal changes of the air and blood, therefore, are rapidly effected, rendering frequent renewals of air necessary.

In birds the structure and offices of the lungs are similar to those in mammalia, but, in addition, the air is also necessary in them, to render the body buoyant, that they may wing their way through the atmosphere. For this purpose a number of the air-tubes, instead of terminating in the pulmonary tissue, open into large sacs, situated both in the thorax and abdomen, for the reception of air, and likewise extend into several of the bones, which are hollow and filled with air, thus combining strength and lightness. These reservoirs regulate the specific gravity of the bird, as the swimming bladder does in the fish; in fact, they are so many internal balloons. An excellent example of modification to circumstances is found in auks and guillemots, so abundant on our shores. These birds, in diving either in quest of their food or to escape danger, use their wings in the same way as in the air; in fact, they fly through the water. To enable them to adjust their weight in order to fly in water, their muscles of expiration are very powerful, so that they may adequately embrace the reservoirs, and thus expel the necessary quantity of air when the bird dives. A sufficient quantity, however, for the changes of the blood still remains, enabling the bird to continue in the water for a considerable time. As soon as it reaches the surface, the reservoirs are again filled, so that the body is lightened, and the bird may now mount into the atmosphere.

In reptiles, a portion only of whose blood is exposed to the air in each complete circulation, and in which the changes consequent to its exposure to air are not so unremitting, the proper pulmonary tissue is much more limited. The cells in several, as the turtle tribe, are very large, accompanied consequently with a diminution of air surface; while others have large reservoirs appended, as in birds, but for a different reason. In birds the reservoirs are for the purpose of adapting the specific gravity in order to enable them to ascend in the atmosphere, while in serpents they render frequent renewals unnecessary. Serpents swallow their prey whole, and as they generally feed on animals whose diameter is greater than their own, the act of deglutition may not be completely effected for days, during which, from the mouth remaining open, the windpipe compressed, &c., no fresh air can be obtained. Those internal receptacles, along with the action of the skin, however, furnish all that is required for producing the necessary influence upon the blood.

In mammalia and birds the means by which the air is drawn in and expelled is essentially the same as we have described it to be in man; but in reptiles the manner in which it is introduced is very different. Several of this class of animals, from the structure of their bodies, cannot have the chambers in which the lungs are contained enlarged and diminished,—for example, the turtles and tortoises; while others have no ribs to be subservient for any such purpose, as frogs and toads. Another plan is consequently adopted by the action of the parts surrounding the orifice of the windpipe: the air is forced down into the lungs and cells. If a frog be watched, it will be perceived that the animal keeps the mouth shut, and that beneath the lower jaw the throat is in constant motion. The air being received by the nostrils, and prevented from again escaping by a valve, it is then by the action of the throat pumped down into the lungs. If the frog's mouth, therefore, be kept open, the animal will be as certainly suffocated as the dog is by tying a rope round his neck.

We are told, "And the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life, and man became a living soul." From the beginning, therefore, the importance and absolute necessity of this function to life must have been acknowledged. But the manner in which it acts has been little understood.

The ancients believed that breathing was necessary in order to keep up the internal fire which they supposed was situated in the left ventricle of the heart—a fire which they stated was not of the gross nature of common fire, which destroys, but a living fire of the essence of the stars, which sustains life, and supports and cherishes the whole system. When this fire was discovered to have no other existence than in the imagination, and it was found that a very large quantity of blood was sent to the lungs, it came to be supposed that the air had some influence upon the blood.

When mechanical laws were had recourse to in order to explain almost all the phenomena of life, by some it was stated that the blood was rarefied from exposure to air, and by others that it was condensed.

Chemistry was next brought forward, in order to explain the manner in which the air and the blood mutually affect each other; but even the chemists are not agreed as to the precise manner in which the changes which take place are brought about. It is not our business here to enter upon the merits of the various opinions that have been and are even now subjects which have excited keen discussion, and called forth the powers of the most distinguished of those who have exerted their talents in this department of human knowledge. It will be sufficient to state what appears to us best to accord with the facts which have been ascertained. We shall find that it is not by confining our attention to one train of facts merely that we can arrive at a satisfactory solution; that it is not merely sufficient to take under consideration the nerves or the blood-vessels, or the changes produced upon the blood and upon the air, in order to enable us to understand what actually takes place; that we must rather reflect upon the joint co-operation of the whole, before we can arrive at a just appreciation of the subject.

The atmospheric ocean, for existing in which we are constructed, is estimated by natural philosophers to be about 45 miles in height. Whether it be subject to regular periodical motions, such as the tides of the ocean of waters, has not been fully ascertained. From its being a gaseous fluid, it is exceedingly susceptible of motion; it is therefore seldom still, but more or less agitated, from the softest breeze to the most boisterous and destructive tornado. This incessant motion has the most beneficial effect upon its salubrity, and produces important results to the whole animated kingdom. It presses at the level of the sea with the weight of about fifteen pounds to the square inch. This weight, however, is liable to be increased or diminished by a variety of circumstances—by temperature, electric condition, and the quantity of moisture it may hold in solution. As we ascend in the atmosphere, and consequently diminish its depth, the pressure is diminished. The inhabitant of the plains of Mexico or Quito in South America sustains a much less degree of atmospheric pressure than the native of the sea-beach, the air in these high regions being more rare, and an equal quantity occupying a greater bulk. It is therefore observed that in the inhabitants of these mountainous regions the chest is more expanded, from the habitual necessity they are under of dilating it to the utmost to obtain the necessary quantity; and that when they descend to the low country, an uneasy sensation is experienced in the chest, from the same cause which produces the distress of breathing in descending in the diving-bell—that is, from the exposure to unwonted atmospheric pressure or weight. On the other hand, the native of a low country, on climbing a mountain, feels, as he ascends, an uneasiness about the chest, and an indescribable feeling in respiration, accompanied with general languor and inaptitude to muscular exertion. It is from the diminution of weight according to the diminished depth of the atmosphere that the height of mountains or the ascent in a balloon is ascertained by the barometer, and that water boils at a lower temperature at the surface of the sea than at the top of a high mountain; so that if we could ascend high enough, boiling water would not cook an egg.

From the manner in which inspiration and expiration are carried on, it will be evident that without this pressure they could not have been performed; and that, in fact, the instruments by which they are effected are as much made for the conditions of the atmosphere as the atmosphere is for them. We are too apt to think that when we find external objects so admirably adapted to us and all our wants, that they have been merely created for our gratification and necessities; whereas it will not diminish the gratitude we ought to feel to the beneficent Author of both to know that they are and were created in the most perfect adjustment and accordance with each other.

The weight of the atmosphere is also influenced by the quantity of moisture it contains, and the quantity of water which it is capable of holding in solution varies according to the temperature and electric condition. Watery vapour is lighter than the same bulk of atmospheric air at the same temperature. The greater the quantity of water therefore in the air, other things being considered, the lighter will be the mixture, and the less the pressure upon the surface of the earth. Hence the barometer is employed as a hygrometer to measure the quantity of water the air may hold in solution, and is the most popular weather-glass. When the air is light and the mercury falls, rain is anticipated. When it rises, fair weather is prognosticated. The temperature of the air influences to a very important extent its power of dissolving and holding water in solution. Hence, in hot climates, although there is actually a much greater quantity of watery vapour in the atmosphere than in cold, so perfect is the solution that the air is clear and transparent. Its weight, however, is not so different as might have been anticipated; for another agent comes into operation. The heat causes expansion of the air, so that the atmospheric ocean is much deeper at the equator than at the poles, and what weight is lost by temperature and moisture held in solution is gained by the height to which the atmosphere reaches. Perfectly dry air has so strong an attraction for water, that it greedily seizes upon it from substances containing moisture, with which it comes in contact. This avidity is vastly increased by a high temperature. Our bodies, composed as they are to a very considerable extent of fluids, cannot be exposed with impunity to such an atmosphere. Hence the deadly effects of the simoom of Africa, and the burning pungent thirst of the deserts of Arabia, which in our climate can only be conceived in imagination.

The electric fluid, whether contemplated in the tranquil movements of the needle of the mariner, as bursting forth from the thunder-cloud, or controlled and directed by the electric eel or torpedo, is universally diffused; and undoubtedly, though we are yet unable to show how or in what way it may constantly be exerting its influence upon our own bodies, its effects must be neither very limited nor unimportant, particularly in such a function as respiration, where a fluid like the air, so much under its influence, is altered, and the evident chemical changes which take place in the blood, are produced. We have thought it necessary to advert to electricity, in relation to respiration, not that it has hitherto explained to us any of the functions more immediately connected with breathing, but because, as our knowledge increases with respect to it, we may expect that electric action will clear up much that is now obscure and undetermined; and therefore, in the consideration of the operations which are carried on in living bodies, it ought not to be entirely neglected. In considering facts which have been already ascertained, we should not think that other agencies may not come into operation, although, in the present state of our knowledge, we may not be able fully to appreciate them.

The atmospheric air, like other gaseous substances, is a bad conductor of heat, yet, from the facility with which the different particles of air are moved and intermingled with each other, a rapid diffusion of heat takes place, so as soon to establish nearly an uniformity of temperature under the same climate and other circumstances. The temperature of the atmosphere is affected by a great variety of causes—by winds and currents of air, by the tides of the ocean, by the evaporation of water, and, above all, by the influence of the sun. In the torrid zone the air is generally nearly of the same temperature as that of the blood of man, and frequently above it; while about the frigid poles it occasionally falls, as ascertained by Captain Back, to 60° below zero of Fahrenheit's scale; and yet in these two extremes man is capable of existing, for by the combined exercise of his intellectual and corporeal endowments in defending himself, he can defy the burning rays of India or the freezing blasts of Greenland.

The constitution of the air has been found on chemical examination to consist of oxygen, nitrogen, and carbonic acid gas. Oxygen is that principle to which the air has been considered chiefly to be indebted for its power of sustaining animal life, and therefore it has been called vital air. When, however, an animal is forced to breathe pure unmixed oxygen, it becomes diseased, and sooner or later life is destroyed. The proportion in which the three gases mentioned enter into the composition of the air is as follows:—oxygen constitutes one-fifth, nitrogen the other four-fifths, and carbonic acid only about one two thousandth part. Nitrogen was at one time termed azote, from its being found that when animals were plunged into it they soon died. It was therefore supposed to be essentially inimical to life. It is now ascertained that, if not necessary, which it most probably is, it is by no means directly injurious to life. Whether carbonic acid, in the quantity in which it is found at all heights of the atmosphere which have hitherto been examined, be of any utility in the function of respiration in animals or not, it is well ascertained that it executes a very important office in the vegetable kingdom. Oxygen and nitrogen have hitherto resisted all means which have been used in order to decompose them, and are therefore held as being simple bodies; while carbonic acid is ascertained to be a compound of one equivalent of oxygen and two of carbon.

Examining the changes produced upon the air, we shall find it affected in its rarefaction, temperature, moisture, and chemical constitution.

In considering the respiratory movements, we have already shewn that rarefaction of the air takes place during inspiration, and that it is one of the necessary steps in the performance of that function. With respect to temperature, from the law by which heat has a tendency uniformly to diffuse itself, and bring neighbouring bodies into a state of equilibrium in this respect, the air and the interior of the body into which it is received soon become of the same temperature. The temperature of the air we breathe being generally lower than that of the body, particularly in cold climates, it soon becomes assimilated to the heat of the body. The breath expelled is therefore warmer than the surrounding atmosphere, and thus a considerable quantity of heat is constantly carried off. Thus, when we are unusually heated, either from exercise or disease, or from the state of the weather, we breathe more frequently; we pant and draw in large breaths, and rapidly renew them, so as to get quit of a quantity of the heat which oppresses us; and this we do, not from any knowledge we have that by such means we shall relieve ourselves, but instinctively; and therefore we see that the dog and the horse use exactly the same means for the same ends. So evident is this cooling effect of respiration, that it was at one time considered as the only purpose which it served; while of late respiration has been held as the only source of the heat which animals are capable of generating. The connexion, however, between respiration and the generation of animal heat, will be postponed till we have reviewed the chemical changes which the air and the blood undergo.

The most superficial observer must be aware that watery vapour is exhaled with the breath. If we breathe upon the surface of a mirror, or on a plate of burnished metal, we perceive it deposited, and rendering the surface dim; or on a frosty day, from its sudden condensation, it becomes a visible vapour. In the arctic regions, when the whale comes to the surface to breathe, the vapour in the expired air being suddenly condensed, forms a cloud which may, in a cold clear day, be seen at the distance of upwards of a mile, warm air having a greater capacity and attraction for water than cold. The air inspired having its temperature augmented, has consequently its capacity and attraction for moisture at the same time increased. It is now well ascertained that animal membranes, thicker and of a much denser texture than that which separates the blood and the air from each other in the lungs, readily admit of the transmission of gases, vapours, and fluids, and that such transmission takes place even more rapidly through living than dead membranes. It is thus easy to conceive how the water may pass from the blood to the air, and be carried off in the breath. With respect to the quantity thus removed, it must be evident that it will vary according to different circumstances. When the circulation through the lungs becomes hurried, and the respirations full and frequent, as from exercise, a greater quantity is carried off, as may be noticed in stage horses in a clear frosty day. A dry atmosphere, from the greater appetite it has for moisture, will more readily absorb a larger quantity. Though, from its more perfect solution in such air, it does not become sensible in the breath. There being an intimate sympathy between the skin and the lining membrane of the air-passages, they become reciprocally affected by various influencing causes. Thus, if the perspiration from the external surface of the body be suddenly checked, the balance of the circulation becomes affected; the blood is impelled to the internal parts, and pulmonary transpiration may be increased, so as in some measure to compensate for the check that of the skin has sustained.

On the contrary, an indolent and inactive life, a moist atmosphere, and a free and copious perspiration, will tend to diminish the quantity carried off in breathing. Various other causes, from the state of the constitution in health and disease, particular kinds of food, regimen, and medicines, will tend to affect the quantity of the thinner part of the blood removed from the lungs. Any attempt to estimate the quantity daily exhaled in this way must necessarily be beset with many difficulties, and an approximation only to the truth can be arrived at. According to good authorities, the amount is rather more than a pint of fluid in twenty-four hours in an adult man under ordinary circumstances.

When a fluid passes to the aeriform state, a large quantity of heat is absorbed, and becomes latent. If the hand be moistened with spirit or ether, and freely exposed to the air, evaporation rapidly takes place, producing cold in consequence of the heat necessary to the condition of vapour being abstracted from the hand. If a pint of fluid be carried off in the breath every twenty-four hours, a considerable quantity of heat must in this way be daily expended. Consequently, in this respect, respiration becomes a cooling process. From the exercise of the function of respiration, therefore, heat is expended in two ways, 1*st*, by the temperature of the air inhaled becoming raised to that of the body; and 2*dly*, from the caloric necessary to the constitution of the vapour of the breath.

The fluid of the pulmonary transpiration is not to be confounded with the thick viscid secretion which we cough up, and which forms the matter of expectoration,—a secretion furnished by numerous little follicles scattered over the surface of the air-passages, and which is deposited upon the lining membrane for its defence; while the pulmonary transpiration is derived from the thinner and more watery part of the blood, by the removal of which the blood becomes condensed in passing through the lungs, in proportion to the quantity of the water thus removed. With respect to the source of this vapour, it has been supposed that the water was formed in the lungs by the direct union of its elements; that the hydrogen of the blood combined with the oxygen of the air, and that during the union a considerable quantity of caloric was extricated. This opinion is, however, now set aside, and the vapour is held as being entirely derived from the serous part of the blood. When we consider that the air drawn into the lungs comes in contact with an extensive surface of moist membrane, and that the serum of the blood can easily permeate the membrane; and further, that the extreme vessels, in their state of vital activity, may exhale more or less freely according to different circumstances, it is not difficult to understand the source from whence it is derived. We know that other matters besides the thinner part of the blood are carried off in this way. Hence, when a person has partaken of a dish seasoned with onions or garlic, or after he has swallowed ardent spirits, these substances are shortly after detected in the breath; and hence, too, in a contagious disease like typhus, the breath of the patient becomes loaded with the poisonous miasmata, and may thus communicate the disease to a person in health. Hence the precaution which ought to be used in attending upon the sick under such circumstances, in order to avoid receiving immediately their breath into our own lungs. The breath may also be vitiated from a depraved state of digestion, when, instead of a sweet and nutritious chyle being produced, a crude and ill-digested matter is introduced into the system, tainting the breath, as well as disordering the general constitution.

The atmosphere, consisting as it does of oxygen, nitrogen, and carbonic acid, is changed by respiration: the oxygen is diminished, the nitrogen remains much the same, and the carbonic acid is increased. If an animal be confined in a given quantity of air, it soon dies, even when means are taken to remove the carbonic acid which is exhaled; and if such air be tested, it will be found that the oxygen has been much diminished, but that the nitrogen remains as before. In all circumstances, and in all animals, a quantity of oxygen thus disappears, though the amount varies much in different animals, and in the same animal in different states of health and other circumstances. Quadrupeds and birds expend a much greater quantity than animals lower in the scale. Although the nitrogen in general be but little affected, still occasionally it has been found either increased or lessened, most probably according to the wants of the system at the time. Oxygen, nitrogen, carbon, and hydrogen, are the chief elements of which the body is composed. Of these are formed the muscles, the tendons, ligaments, and membranes; the nerves, blood-vessels, glands, and the blood itself; as well as the various secretions which are elaborated from it. Though there are other elementary bodies, still they are confined to particular tissues, or are found only in very small quantities, as the lime of the bones, the iron of the blood, and the sulphur of some secretions. All these elements must be derived from without, for we can scarcely admit of a creative power even in living animals. The most that can be ascribed to them is the power of appropriating and combining the elements of which they are composed, according to their exigencies. Now, many animals subsist upon food which contains little or no nitrogen, though it be found abundantly in their structures. There is no other source by which they can so readily obtain it as from the air by respiration. On the other hand, if an excess of nitrogen at any time exist in the system, the superfluous part may be carried off by the lungs as well as by other channels, and thus account for the increase or diminution of the nitrogen which has been observed.

That carbonic acid gas is given off in the breath may easily be proved, and no way more readily than by breathing into lime-water, when it will combine with lime held in solution, and form with it a sparingly soluble compound, which is thrown down, rendering the solution turbid.

Different opinions are entertained as to the source of this carbonic acid. Some believe that the oxygen of the air is attracted by the venous blood, and combines with its carbon, forming carbonic acid; others that the carbon passes from the venous blood to unite with the oxygen in the cells of the lungs. According to these two opinions, the carbonic acid is considered as formed in the lungs, and carbon is extracted from the blood; the difference between them being, whether the oxygen be attracted by the blood in the vessels, or the carbon be secreted by the vessels, so as to combine with the oxygen of the air. In either case, supposing no water is formed by the union of oxygen with hydrogen from the blood, the quantity of carbonic acid exhaled ought always to account for the quantity of oxygen which disappears, knowing as we do the amount of oxygen in a given bulk of carbonic acid gas. But it has been found that we cannot always thus account for the oxygen which disappears during respiration; for sometimes there is more carbonic acid given off, and sometimes less, than is indicated by the expenditure of oxygen. Another view has consequently been taken, ascribing the loss of oxygen which the air sustains to the blood, in its passage from the arterial into the venous pulmonary capillaries, attracting and combining with it during the change from the dark purple to the florid red; that is, when it undergoes its specific change in the lungs. It is believed that the oxygen which thus enters the blood gradually unites with carbon, more especially in the capillaries between the arteries and veins of the system, where the converse change to that which is effected in the lungs takes place, and that the venous blood, on being transmitted to the lungs through the ramifications of the pulmonary artery, secretes or exhales carbonic acid. According to this view, the blood, during its passage through the lungs, throws off the carbonic acid which is formed in its circulation through the system, and absorbs oxygen to unite with carbon in the system. A modification of this theory is entertained, that it is not the oxygen alone which is absorbed by the blood in the lungs, but a portion of the entire air is taken up, and the quantity of oxygen and of nitrogen retained, according to the wants of the system; so that if nitrogen be not required, an equal bulk of it is exhaled as absorbed; and thus we account for its being generally apparently unaffected by respiration; while, if necessary, a portion may be retained or thrown off as requisite, accounting for its diminution in some cases and its increase in others: Further, that the quantity of carbonic acid given off also varies according to the state of the system in general, without any direct reference to the oxygen taken up.

The quantity of carbonic acid given off has been found to vary according to different circumstances. As its generation seems connected with and dependent upon some of the most important of the vital functions of animals, we may advert, for the sake of illustration, to some of the conditions on which the variations seem to depend. It has been observed to be affected by the time of the day, the period of the year, the age of the animal, the nature of the food, &c. We are indebted to Dr Prout for the first notice as to the variation of the quantity according to the hour of the day. He ascertained that the greatest quantity is given off about noon, or between eleven o'clock A. M. and one o'clock P. M.; that the quantity diminishes till about eight in the evening, when it remains nearly stationary at the minimum till the following morning between three and four o'clock, when it begins to increase, till it again reaches the maximum about noon. There are so many changes to which our bodies are subject, both in health and disease, dependent upon causes which have hitherto eluded the most careful researches, that on the announcement of a new and interesting fact like this, we become anxious to inquire whether we can from thence obtain any elucidation of phenomena with the existence of which we are sufficiently familiar, but as to the causes on which they depend we are in profound ignorance. Among these phenomena, the causes of which we are ignorant, may be mentioned the exacerbations and remissions which appear in regular succession in agues and other diseases, which it is possible may have some connection with the same causes that originate the differences as to the amount of carbonic acid at different periods of the day.

The season of the year has also been found to influence the generation of the carbonic acid; in winter a greater quantity being expelled from the lungs than in the summer. Young animals generate less carbonic acid than adults. The nature of the food and drink has also a considerable effect. Vegetable diet lessens the quantity, as also do ardent spirits, violent exercise carried to fatigue, sleep, and the depressing passions and emotions of the mind.

It appears that the causes which tend to diminish its production are more various than such as have an opposite tendency. Generous diet, moderate exercise, and a cheerful state of mind, promote its formation. Or, in other words, whatever tends to keep up a vigorous and healthy state of the body, increases it, and when the functions are carried on with due alacrity and ease, it is more readily formed. On the other hand, all those causes which diminish the vital powers, and depress the energies of the system, have a contrary tendency.

The condition of the skin has likewise a considerable influence. For, in this respect, besides others, there is a reciprocal connexion between the skin and the lungs, which ought not to be overlooked. The skin produces upon the air similar changes to those which result from the action of the lungs. In some animals, as in toads and frogs, the skin may effect the necessary changes where the function of the lungs is altogether arrested.

In some experiments, where a toad was surrounded by a thick coating of Paris plaster, it continued to live for some time, the air which penetrated the pores of the plaster being sufficient to prevent the extinction of life. We are in this way enabled to understand how that animal has been found alive, imbedded in a sandstone rock, belonging, as it does, to a class of animals which require a less supply of air, and moreover being furnished with external integuments capable of effecting the changes upon the blood through the medium of the air in contact with them. In so confined a situation, where many of the functions are suspended, as muscular motion, life remains, though of course in a very dormant and inactive state. Even in man the skin produces the same changes upon the air as are produced by respiration. The extent of the effect upon the air, and the quantity of carbonic acid formed, will vary with the health and constitution of the individual, and also according to the climate. Dr. Copeland mentions, that in a series of experiments performed by him on his own person, and on a negro, whose chest was about the same capacity as his own, he, Dr C., produced a larger quantity of carbonic acid from the lungs; but that the negro exhaled more from the surface of the body, in the proportion of three to two. This fact is interesting, in reference to the adaptation of negro constitution to a hot climate. We shall again have occasion to refer to this subject when we come to treat of the production and regulation of animal temperature.

The alimentary canal, too, lined as it is throughout by a membrane similar in structure, and in some respect analogous in function to that which covers the air-tubes, is known to produce upon air effects identical with those effected by breathing. From the examination of the air found in the stomach and different parts of the intestinal tubes, it has been found that while in the stomach it is similar to the external atmosphere, while in the intestine beyond, the oxygen entirely disappears, and is replaced by carbonic acid; and there is little doubt that the inner membrane of the alimentary tube performs this office to no small extent in many of the inferior tribes of animals. It may be observed with respect to the beautiful gold fishes so often kept in vases as pets, that when, from neglect, the water has not been duly changed, and when therefore it has become vitiated, the little creatures often come to the surface for the purpose of obtaining a mouthful of air, which they swallow. The lining membrane of the stomach then takes on vicariously the office of the gills. After the air has been changed, they may be observed to reject it again by a kind of eruction; so that in this way they are enabled in some measure to obviate the evil consequences which result from the unhealthy state of their surrounding medium.

It has been said that art requires to be abundant in causes which produce but few effects, while nature is sparing in causes, but abundant in effects. It may be true that the operations of nature may be traced up to a few leading general laws, or secondary causes; but in each individual example of the functions of living animals, such an infinite number of subordinate causes are brought into play, that even reversing the above rule would come as near the truth. In a vague and superficial manner it may be said that the blood is circulated by the heart and blood-vessels; that the function of respiration is performed by the lungs, and that the food is digested by the stomach; but when we come to study more closely any one of these functions, we soon find such a vast number of modifying causes, that the mind is at first apt to get bewildered; or we may fall into the error of attributing too much to one of the causes which we find in operation, and neglect others which may exert a very important influence over the proper performance of the function under our consideration. When we state that oxygen is abstracted from the air, and that carbonic acid is exhaled by respiration, we state the truth, but not the whole truth, for we find that the same is done by the skin and by the alimentary canal, though in a subordinate degree.

Changes upon the Blood.—From what has just been stated respecting the changes which the air undergoes in respiration, it is obvious that the blood, being subservient to them, must itself become altered. The alterations effected upon it may be considered in respect to its colour and density, its chemical constitution and temperature, and its vital properties.

Colour and Condensation.—When a vein is opened, the blood which flows is of a dark purple colour. On exposure for a little time to the air, it assumes a bright scarlet hue; nor is immediate contact with the air absolutely necessary to produce this effect, for, if received into bladders much thicker than the delicate membranes which separate the air from the blood in the cells of the lungs, a similar change will take place. The blood, on exposure to the air in the cells of the lungs, is seen to change from purple to florid red.

It has already been stated, that every day upwards of a pint of the watery part of the blood is carried off in the breath, in a man of common size, under ordinary circumstances. The blood flowing to the left side of the heart will be thereby so far condensed.

Chemical Constitution and Temperature.—As has already been shewn, during respiration the air evolved contains less oxygen and more carbonic acid than that which is inhaled: in so far does the blood become chemically changed, that it now will contain more oxygen and less carbonic acid. Other alterations in the chemical condition between the venous and arterial blood are without doubt effected, but elude the means we at present possess of satisfactorily estimating them. A slight difference has been observed to take place in the heat of the blood, there being a temperature about one degree higher in the scarlet than in the purple.

The blood in the living body is not to be considered merely a very compound mixture of water, colouring matter, albumen, fibrin, with several salts, &c., but a living substance, endowed with the peculiar vital properties of the system to which it pertains. These properties are different in the two kinds of blood. Arterial blood is necessary to the due contractility of the muscles, to the all-important functions of the brain, to the formation of the secretions, and even in an important degree to the office of the lungs themselves. In becoming arterialized by the function of respiration, therefore, the blood obtains renewed vital energies.

In connexion with the function of respiration, we shall consider animal temperature, voice, the effects of different gases, and lastly, the phenomena resulting from the suspension of breathing.

Animal Heat.—The term caloric has been applied to the cause which produces the sensation of heat. It is necessary to have recourse to some such specific name; for if we were to depend on our sensation as to heat, our conceptions would be vague, indefinite, and often erroneous. Let two persons enter a room in which the temperature is, say 45°; the one coming from a highly heated apartment, the other after having been for some time exposed to the external air in a frosty night. To the first the room will appear intolerably chill, to the latter comfortably warm. Or let a person put for some time one hand into a basin of water as warm as he can bear it, his other into a basin containing ice-cold water; then let both waters be poured into one vessel, and let him plunge both hands into the mixture; now he will find that to the one hand the water appears cold, and to the other warm. Further, in a calm frosty day we may walk abroad without experiencing the necessity of additional clothing; but if a breeze spring up, even though the temperature become considerably elevated, we immediately become sensible of the want of protection; so that were we to trust to our feelings in these cases, we should often be misled.

Similar quantities of different bodies at the same temperature do not contain the same quantity of caloric, or matter of heat. Thus, a pint of water at any given temperature contains twice the quantity of caloric that a pint of olive oil does. This difference in bodies is termed their capacity for caloric. Water, therefore, has twice the capacity for heat that olive oil has. The same body in different conditions has its capacity for caloric changed and adapted to each state. When ice is converted into water, the capacity for heat in the fluid water is much greater than in the solid ice; and when water is converted into vapour, the capacity is vastly increased;—so that the same substance in these three conditions possesses very different capacities for heat.

When two bodies enter into combination with each other, the product of their union having a less capacity for caloric than the two constituents, heat is given off. Hence, under whatever circumstances oxygen and carbon unite, there is an extrication of caloric. We have an example of this in the common fire, where the carbon of the fuel unites with the oxygen of the air in the chamber, forming carbonic acid, the union being accompanied with evolution of heat and light. Fermentation furnishes another example. In living animals a combination takes place between oxygen and carbon; here, therefore, there must be a liberation of caloric.

Caloric has a tendency to diffuse itself, so as to bring contiguous bodies to an uniform temperature. When a warm body is placed in a cold medium, caloric is carried off, and the heat reduced in two ways; *first*, by contact with the colder body, when it is said to be removed by conduction.

Different substances vary very much as to their power of conducting caloric. If iron, glass, and fur, at the freezing point, be brought in contact with the body, although the three be of exactly the same temperature, yet very different sensations will be experienced. The iron will feel intolerably cold, the glass less so, and the fur will scarcely appear to be different from the warm hand. This arises from the difference of their conducting power; the iron is an excellent conductor, the glass much inferior to it, and the fur one of the worst conductors known.

2dly, Heat is reduced in warm bodies by what is termed radiation. If a red-hot ball of metal be suspended in a room, caloric darts off from its surface in all directions, until its temperature is brought into equilibrium with surrounding bodies. Radiation of caloric, like conduction, varies very much in different substances. Dark rough surfaces radiate much faster than bright polished surfaces. Colour has a considerable influence on radiation, black producing the greatest and white the smallest effect.

Lastly, bodies differ from each other in their power of absorbing caloric; this, however, is always in proportion to the radiating power, those bodies which radiate caloric readily being active in absorbing it, while slow radiators are slow in absorbing. It is necessary to bear these facts in our mind when we enter upon the consideration of the manner in which organized bodies regulate their temperature. Among other properties of living beings, the regulation of the heat of their bodies, so as to adapt it to their individual constitutions and habits, and to the circumstances in which they are placed, is one of their most general characteristics, most necessary to their well-being, and indeed to their very existence in a living state. Where the medium in which they exist is such as is subject to but slight variations of temperature, and these brought slowly and gradually about, as in water, the temperature in general differs but little from that medium. It was not necessary, therefore, that the inhabitants of the waters should be furnished either with the means of generating much heat, or with clothing for its preservation.

Water, being an excellent conductor of caloric when compared with air, rapidly abstracts heat. Accordingly, we find that such inhabitants of the waters as sustain any considerable temperature above it, are furnished with admirable means for its preservation. The whale tribes have smooth and polished skins, which do not readily throw off the heat, underneath which there is a large depositation of oily fat, a very bad conductor of caloric. They are thus clothed in the best manner possible for the retention of their internal heat. Seals and walruses have clothing fashioned on the same principle.

On the other hand, such living bodies as inhabit the air, exposed as it is to so many vicissitudes of temperature, require not only the power of generating heat, but also the means for its regulation, according to varying circumstances. The average temperature of man in a state of health is about 97° or 98° of Fahrenheit's scale. In quadrupeds it reaches in some as high as 100°, and in birds to 107° or 108°.

We shall, *first*, inquire into its source and distribution through the body; and, *2dly*, into the manner in which it is regulated when the body is exposed either to very high or very low temperatures.

No sooner had Black discovered the nature and composition of carbonic acid, and the large quantity which was given off by animals during respiration, than it struck him that here might be found an explanation of animal heat, which, notwithstanding some vague suggestions of Mayow, was previously very conveniently stated to be an innate property of living bodies, a satisfactory mode of getting quit of all such difficulties at once, without any farther trouble! Black's idea, although shewn to be untenable, roused inquiry, and laid the foundation of all the subsequent discoveries and acquirements which have since been made. It would be out of place here to enter into the various steps in the progress of our knowledge respecting this subject.

It has been stated that more carbonic acid and less oxygen are thrown off by the breath than are inhaled by it. An union of oxygen with carbon, to form the carbonic acid, must therefore be effected in the body, and consequently an extrication of heat. It has also been stated that when substances pass from one condition to another, their capacity for heat is changed. Accordingly, when venous blood is converted into arterial, an alteration in this respect is effected; as also when it is again changed from arterial to venous.

A question which has been much discussed is, where does the union of the oxygen with the carbon take place? Is it in the lungs? Or is it in the system? Those who hold that the union is effected in the lungs account for the temperature of these organs remaining the same as in the neighbouring viscera, notwithstanding the extrication of caloric which necessarily takes place, by assuming that this caloric immediately enters into the arterialized blood, the capacity of which has been increased on its conversion from the venous state. The arterial blood propelled by the left ventricle of the heart penetrates through the arteries into every tissue of the body. In the extreme branches of the arteries it is again venalized, in which state the blood has a less capacity for caloric. The caloric is consequently set free, and supports the temperature.

Those again who contend that a portion of the entire air enters into combination with the blood, account for the phenomena in the following way:—They assert that the union between the oxygen and the carbon does not take place particularly in the lungs, but in the extreme arterial capillaries of the whole system, where the blood is changed from arterial to venous, and that at the same time the caloric is set at liberty to support the animal heat.

It thus appears that both agree that the immediate source of animal heat is in the union of oxygen with carbon; both agree that the liberation of the caloric occurs where the blood becomes venalized, the difference between the parties being as to the place where the union is effected,—

a difference which the student of general physiology may safely leave them to settle between themselves, at the same time thanking them for the patience, diligence, and success with which they have established the two important positions on which they are agreed, and which probably would not have been placed on so satisfactory a basis had no rivalship taken place between them.

It would thus appear that the source and distribution of animal heat is in the mutual exercise of the functions of respiration and circulation. Others, however, have attempted to overthrow these views as to animal heat by mutilating animals in various ways,—justly considering that it is both a more easy and successful plan, in order to gain notoriety, to endeavour by ingenious objections to upset a generally received doctrine, than to establish one equally good in its place.

It is by no means here intended in the slightest degree to condemn the performance of experiments on living animals in order to advance knowledge and establish truth. He must be very ignorant indeed who is not aware of the many valuable facts which have been ascertained in this way, which otherwise must have been still unknown, and by which much suffering has been obviated, and many a valuable life preserved. But cruel mutilations of living animals, either in order to discover something at haphazard, or to give a show of support to the crude fancies of a loose imagination, ought, to say the least, to be met with the contempt and neglect they so richly deserve. Not so where the experiments are such as necessarily deprive the animal of feeling, or where steps have previously been taken to effect the same purpose: then no objection can be started on the score of humanity; but in all such cases it is to be recollected that they are mutilations at best. Where, therefore, the nervous system has been destroyed to such an extent as it sometimes has been, in order to shew that such destruction was accompanied with loss of power in the production of heat; instead of agreeing that animal heat consequently results from the nervous system, it is much more reasonable to believe that the result arises from the stop that is put to the due performance of those functions on which its production more immediately depends.

That the source and diffusion of heat through the body depend on the combined action of the functions of respiration and circulation, is supported by a great number of phenomena both of health and disease. To some of these we may now advert. Whatever tends to increase these functions increases the temperature, and conversely, whatever lessens them produces a diminution of heat. Exercise being accompanied with an exhilaration both of circulation and respiration, produces, in the coldest weather, a glow of heat over the whole body. When the hands become benumbed with cold, friction, by increasing the circulation, soon restores the warmth. For the same reason, where exposure to cold has induced dangerous symptoms, one of the first circumstances to be attended to is the restoration of the circulation. At the same time, it is necessary to do this with the utmost caution. Warmth, friction, and other means ought to be gradually exhibited. Violent applications at first are likely to be followed by the worst effects. Experience has pointed out to the Greenland sailor that the best mode of restoring the frostbitten extremities is to rub them with snow, and that the sudden approach to a fire would probably produce the death of the part, at any rate, violent and protracted inflammation and its consequences. He is at the same time totally ignorant of the principles on which this judicious practice is founded; consequently, upon any unusual occurrence, cannot avail himself of it. A few years ago a very fine healthy young man fell overboard from an open boat, at some distance from his ship in Greenland, the temperature at the time being considerably below zero. Before he could be got on board of the ship, his clothes were completely frozen, his extremities benumbed, and he was incapable of voluntary motion in his limbs. Still, however, respiration was carried on, also circulation in the central parts, and his mind remained unaffected. He was carried down into the heated cabin, his clothes were cut from him, and on being wrapt in warm blankets, he was laid before the fire, when hot brandy and water was administered to him. In a short time the benumbed limbs were tortured by the most agonizing darting pains, and in two hours he was dead.

When any organ is brought into a state of inordinate action, and consequently has an increased quantity of blood passing through it, the temperature is elevated. Dr Granville mentions a case (Phil. Trans., 1825) where, during the violent action of the womb in parturition, he noticed the temperature rise as high as 120°,—by much the highest animal heat recorded. In local inflammations, as in whitlow, the temperature of the part affected is raised above that of the surrounding parts. In inflammatory fevers, both respiration and circulation being increased, especially the latter, the burning heat forms one of the most distressing concomitants. In ague, during the cold stage, the circulation is retarded, the blood leaves the surface, and accumulates in the cavities. The surface becomes cold and chilly, accompanied with shiverings. As soon as re-action takes place, the blood is propelled to the surface in an increased quantity, and the temperature soon mounts above the natural standard. On the other hand, during the paroxysm of asthma, where both respiration and circulation are involved, the temperature falls sometimes to 82°.

Small quadrupeds breathe quicker, their motions are performed with greater quickness and vivacity, and they support a higher temperature, than man. Birds inhale a much greater quantity of air than other animals; but, as has been already stated, this is not merely for the purpose of respiration, but to fill the air-bladders by which their bodies are rendered buoyant. Still they breathe very quick, their circulation is very rapid, and all their motions are performed with great force and velocity. The temperature which they sustain is higher than in other animals, their natural standard being the high fever heat of man, 107° or 108°. Reptiles, whose respiration is slow and performed at distant intervals, a portion only of their blood passing through the lungs at each complete circulation, and whose blood is transmitted slowly and sluggishly, have a temperature much lower than man, and therefore are termed cold-blooded. Insects, from the smallness of their size, and the peculiarities of their respiratory and circulating systems, are not easily examined as to the heat they may individually produce; yet collectively this is more easily effected. The bee-hive, when the community are in a state of full activity, has been observed to stand at 100°.

Regulation of Temperature.—This may be considered under two points of view; 1*st*, When the body is exposed to a high degree of heat, how does it preserve its usual standard? 2*dly*, By what means is vital warmth preserved when the body is exposed to very low temperatures? These two questions might be considered together; but there will be an advantage in examining them, in the first place, separately.

The celebrated Boerhaave believed that the use of respiration was to cool the blood, and that a higher temperature than that of the body was incompatible with life. Some experiments, undertaken at his suggestion by Fahrenheit, appeared to confirm this hypothesis. But the thermometer enabling travellers in tropical climates to make accurate observations, it was found that in these regions the heat of the air often rises considerably above that of the blood, and which shewed the fallacy of his opinion. Experiments were instituted to ascertain to what extent the heat might be tolerated. A baker's daughter in France was seen to enter an oven heated to 260°, and remain for twelve minutes without experiencing much inconvenience. Public exhibitors (terming themselves fire-proof) often enter prepared chambers where the temperature is raised to a height sufficient to cook meat, and remain till it is sufficiently cooked. It may be well to notice the effects of heated dry air, vapour bath, and hot water bath. When animals are placed in a small apartment, with dry air heated to 112°, in about half an hour the respirations are quickened, and afterwards become more easy. After remaining for about an hour and a half, on being removed, they gradually recover. In some of the experiments performed on man, different individuals have remained from seven to eight minutes in a chamber heated to 230°, 240°, and 260°. The pulse of a young man, which beat commonly 75, was raised to 164 per minute. Persons unaccustomed to the use of the vapour bath cannot tolerate it much above 100°; but in Russia and Finland, where it is in common use, individuals habituated to it can remain for half an hour with the temperature raised to 160° and 165°. Few persons can remain in the hot bath for many minutes when the temperature is that of the blood.

When the body is exposed to high temperatures, the respirations become quicker and fuller; the blood is propelled by frequent and powerful pulsations, and is determined especially to the surface; and the heat of the body is in a slight degree augmented, but by no means to any thing like the extent that might have been anticipated. In the cases of exposure to high degrees of heat, it was never found to reach what it is observed to do occasionally in inflammatory fever. We have therefore to inquire by what means the living system is capable of resisting these high temperatures, so as to preserve its own uniformity.

Where the heat of the atmosphere is below that of the body, the air, on being inhaled, is soon assimilated to the temperature of the body, and in this way a quantity of heat is carried off.

When fluids pass into the state of vapour, a very large quantity of heat is necessary to them in that condition, which does not raise their temperature. As has been already mentioned, a considerable quantity of watery vapour is exhaled by the breath. Hence in this way a quantity of heat will be removed.

As, however, animal heat is evolved where the arterial blood is changed into venous; and since the effect of heat is to increase the circulation and determine it to the surface, so we find that the uniformity of animal temperature is preserved chiefly in consequence of what takes place on the surface of the body. At all times a quantity of the thinner part of the blood is carried off from the skin, generally in a state of invisible vapour, while in some conditions it is deposited upon it in a fluid form, or sweat. When it passes off in vapour, it is termed invisible transpiration, and when deposited in a sensible state, visible transpiration. The quantity of fluid thus removed from the body varies exceedingly, according to a great many circumstances. The function of transpiration is at all times of the greatest importance to the health and comfort of the individual. It has been estimated that an ordinary-sized man, under ordinary circumstances, loses about two pints of fluid in this way in the twenty-four hours. Heat is one of the chief causes of its increase. By the exercise of this function, a very great quantity of heat must be daily expended. To have some idea of this quantity, we have merely to consider how much heat would be necessary to convert two pints of water to the state of vapour, which is only the average quantity of fluid daily transpired.

The conditions of the air have much influence upon transpiration. The chief are the temperature of the air; dryness and humidity; rest and motion. The higher the temperature, the greater the quantity of water the air is capable of holding in solution; and the drier it is, the greater is its attraction for moisture. We feel much served that persons will continue for hours in a warm room, drinking abundantly, without experiencing distension of the urinary bladder; but when they reach the cool air, the bladder soon becomes distended, and gives warning accordingly. In winter, the superfluous fluids are carried off chiefly by the kidneys, while in summer the skin in a great degree performs this office. There is indeed an admirable balance between these two organs, which is constantly tending either to the one or to the other, according to circumstances. When the heat of the body is elevated, the blood flows towards the surface, and the thinner part is dissipated in vapour, so as to carry off the superfluous heat. When the body is exposed to cold, the tide sets towards the central parts, and the excess of fluids is filtered through the kidneys, to be discharged in the liquid state.

Moderate cold acts as a stimulant to the system. The powers of the digestive organs are exerted with greater energy. They both crave, and are capable of assimilating, a larger quantity of food, and thus furnish to the system the additional fuel which becomes necessary.

Such are the most important facts to which it has been deemed necessary here to advert, with respect to the origin, distribution, and regulation of animal temperature. In the view we have taken, chemical principles have chiefly guided us; but it is to be recollected that these chemical principles are under the control and direction of a living principle, which forces them to act according to its behests, so as to produce results that the chemist in his laboratory in vain attempts to imitate, when manipulating upon dead matter through the medium of dead apparatus, however high may be the genius, intelligence, and dexterity of the director.

From no function are there so many, and so striking allusions to, and images of life and death, as are derived from animal heat. We speak of life's warm stream, the glow of health, &c.; and on the other hand, Byron writes:

meter during our stay in winter harbour, not the slightest inconvenience was suffered from exposure to the open air by a person well clothed, as long as the weather was perfectly calm; but in walking against a very light air or wind, a smarting sensation was experienced all over the face, accompanied with a pain in the middle of the forehead, which soon became rather severe. We amused ourselves in freezing some mercury during the continuance of the cold weather, and by beating it out on an anvil, previously reduced to the temperature of the atmosphere. It did not appear to be very malleable when in this state, usually breaking after two or three blows of the hammer."

It has been found that the power of generating heat varies according to the season, animals possessing a greater power of producing heat in the winter than in the summer. It has also been ascertained that the quantity of carbonic acid formed varies at different periods of the day, a greater portion being given off during the day. Fatigue, depressing passions of the mind, and whatever tends to impair the energies of the system, cause a diminution of the carbonic acid generated, and consequently of one of the principal sources of animal heat. With respect to the causes which tend to the preservation of the uniformity of animal heat on expesure to low temperatures, it is to be observed that it is not meant here to refer to those degrees of cold which are incompatible with the due exercise of the functions of life. Heat causes a determination of blood to the surface, relaxes the skin, and increases transpiration. Cold, on the other hand, repels the blood from the surface, braces and astringes the integuments, and lessens the transpiration. The thinner and superfluous quantity of the circulating fluid is no longer thrown from the surface, but is drained off in the fluid state, principally through the kidneys, and thus all the heat which would have been requisite for its conversion into vapour, is preserved. It may be obgallinaceous birds are capable of running about as soon as they leave the shell, and only occasionally require to place themselves under the sheltering wings of the mother, to receive from her heat and protection, while the callow brood of the pigeons and warblers require the fostering care of the parent, in order to receive the warmth they themselves are for some time incapable of generating in sufficient quantity, however warm the nest may be, or however sheltered the spot. These do not produce, but retain the heat, thereby enabling the parent to leave her nestlings for a little on necessary occasions.

The intelligence of man in most cases raises him above his mere instinctive feelings and propensities. By his reasoning powers he is enabled to control and direct them. Still, however, he is endowed with instincts in common with his fellow creatures. The mother instinctively folds her infant in her bosom, not only because there is placed the fountain from which it derives its nourishment, but because from thence also it obtains that vital warmth which its new-born faculties are yet incapable sufficiently to impart. The infant may be wrapt in the most fleecy swaddlings, the most costly furs, and the softest eider down may be had recourse to; but these cannot communicate heat; they merely retard its escape. Wherever there is a deficiency, heat must be imparted from some source in which it is generated, and no source can equal that which nature points out—the mother. Fashion and philosophy sometimes most mischievously interfere with matters which they but little understand. Infants are sometimes exposed to cold, in order to render them hardy. They are lightly clothed, or daily plunged in a frigid bath, for this purpose. It is true that the more robust may escape without injury, but it is because they are hardy: the more weakly perish. We see few decrepit, feeble, or maimed among savage tribes, because they perish for the want of things necessary to their condition,—those only of iron constitution reaching an age of maturity. A melancholy example of physiological principles misunderstood and misapplied, may be here mentioned. A physician wishing to invigorate the constitutions of his children, directed that from within a day or two of their birth, they should be every morning and evening plunged into cold water, at all seasons of the year. The screams of the little sufferers, and the horror that the very sight of the tub, at all times, even when empty, excited, when they had no other means of communicating the cruelty of the practice, might, one would have thought, have led the fond parent to reflect upon the soundness of his views. But he had no doubts upon the subject. The consequence was, he was deprived of three by consumption at an unusually early period of infancy. Two only escaped, which they did from occurrences in the family taking place so as to cause the neglect of the practice, which, there can be no doubt, led to the fatal event in the other three.

Gradually the functions on which animal heat depends, are developed: the chest expands; the respiration is fully established; circulation is vigorously carried on, not merely for the building up and enlarging the different parts of the body, but also for enabling the muscles, with full effect, to exert themselves in the various motions which from day to day are called forth.

Adaptation to Temperature.—Animals, even in the adult state, present great differences in the power of adapting their constitutions to different climates. Some are limited to a single spot, removed from which they languish and die. The reindeer and the polar bear affect the low temperature within the arctic circle, while the camel pines beyond the limits of the burning desert. Others again more readily accommodate themselves to different climates, and are widely spread over the surface of the globe. Man, by his constitution, has been intended to inhabit every country and every clime; and this he is enabled to do, not only by having recourse to such measures as his reason and experience point out as the best means for his protection, but also because his bodily frame possesses a pliability which adapts itself to the circumstances in which it may be placed. At the same time, by the exercise of his intelligence, he is enabled not only to furnish himself with such clothing as best suits his condition, but likewise to make for himself an artificial temperature. Here we have a striking example of the excellence of reason. Instinct may direct one animal in the formation of a warm nest, or another in the construction of a burrow, which moderate natural temperatures, and economize the natural expenditure of heat; but these are only conservative, not productive measures. Man alone has recourse to artificial heat. By observation and experience he constructs his dwelling, and surrounds himself with an atmosphere in the depth of winter which best suits his feelings, and thus bids defiance to the howling blast, and repels the approach of the severest frost.

At the first glance man might appear the most defenceless of all animals, not only in respect to attacks from his fellow creatures, but also against the elements. But it is clear he never was intended to be a savage. He is gifted with intellect that he may use it, and, by its direction, bring the world under subjection. For him the worm weaves its silken cone; to him the sheep yields its fleecy coat, the ermine its fur, the eider duck its down; the flax presents its pliant fibre, and the cotton tree makes an offering of the coverings of its seed. The shaggy coat protects the bear through the rigours of the arctic winter; but he cannot cast it from him in the warm summer of more temperate climes. The thin-clad monkey may gambol under the burning sun in the forests of the tropics, but he has no protection against the climates of less ardent regions.

Hybernation.—Hybernating animals present some curious phenomena in connexion with the vital functions in a state of torpidity. Birds, possessing, as they do, excellent powers of locomotion, can easily pass from one country to another. Where, therefore, the supplies of food become deficient, and the temperature unsuitable to them, either from deficiency or excess of heat, they are enabled to migrate to countries where subsistence can more easily be procured, and where the temperature is more congenial to them. Quadrupeds being more limited in their locomotive power, are not capable of availing themselves of change of place with the same facility, or to an equal extent. Several, however, do shift their positions according to the seasons, as the reindeer and musk ox of the northern regions. Others are obliged to remain in the same country throughout the year.

Cold-blooded animals, such as frogs, serpents, and lizards, need not here be adverted to, as sufficient examples are furnished from mammalia for the present purpose. The food on which a great number of animals subsist during summer is not to be obtained in the winter. They must therefore seek it elsewhere, or change their diet. Migrating birds have recourse to the former measure, while many which remain with us throughout the year have recourse to the latter. Of our wild quadrupeds, some continue in a state of activity during the winter, searching after food where it is to be had, and sustaining their vital warmth in the depth of winter. Others, impelled by a remarkable instinct, collect food when it can be obtained in abundance at the end of autumn, and store it up in magazines, which are generally deep burrows in the ground, beyond the reach of frost, and lined with substances fitted for the retention of heat. Others, again, living on food which cannot be stored up, as the bat, or not being endowed by any such instinct, as the hamster, possess an organization which in a wonderful manner accommodates itself to the circumstances. On the approach of winter they seek out some convenient retreat, where they are not likely to be disturbed in their defenceless state. Their functions become gradually benumbed, and are carried on merely to a sufficient extent to preserve life in its most subdued state.

In hybernating animals voluntary motion is altogether suspended, so also is the process of digestion; several of the secretions are suppressed, as the saliva, gastric juice, and urine; the senses are likewise sealed up; and the circulation is diminished. The hamster, in which the pulse beats 150 per minute, in a state of activity, has it reduced to 15 in its torpid condition. The dormouse, whose pulse is so rapid as scarcely to be counted when in its ordinary state, has it reduced to the same low standard when torpid.

Respiration is also affected in a remarkable degree, not only in the number, but in the fulness and regularity of recurrence. Marmots, in a state of health and activity, perform about 500 respirations in an hour, but in the torpid state these occur only 14 times during the same period, and are performed at intervals of four or five minutes of absolute rest; neither is the chest enlarged to any considerable extent.

Irritability is much diminished; parts of their limbs may be cut off without the animal shewing any signs of feeling. When the hamster is dissected in this condition, the intestines discover not the smallest signs of irritability on the application of stimulants. During the operation, the animal occasionally opens its mouth, as if it wanted to respire, but the lethargy is too deep to admit its being roused. Those functions on which animal heat more immediately depends, namely, the circulation of the blood; those changes which effect its conversion from arterial to venous, and the process of breathing, are carried on in a very subdued manner; the resulting temperature is accordingly low. The summer temperature of the hedgehog is 100°; in the state of torpidity it is only about 44°. But it is to be observed that it is always from 3 to 4 degrees higher in the central parts than at the surface. The ordinary heat of the marmot is 102°; during hybernation 43°. Hybernating animals thus present to us a very remarkable modification of organization; at one season, when in a state of full activity, supporting animal heat at its highest point; but being incapable of sustaining the vital warmth, in opposition to low external temperature, they are thrown into a peculiar condition, in which life however is not extinguished, but remains dormant in many instances for months.

At the end of autumn, from the abundant supply of food which most of them are able to procure, they retire to their winter retreats loaded with fat. This serves as a reservoir of nourishment sufficiently adequate to the supply of the small expenditure that takes place during their torpid state. On the return of genial spring they are roused from their lethargy, the fat being generally wholly expended. We thus perceive that every fact with respect to the source, distribution, and adaptation of animal heat in these hybernating animals, fully accords with the principles which have been adverted to as the causes of these in animals which support a temperature nearly uniform at all seasons.

Voice and Speech.—The inhalation and exhalation of air may be so modified as to cause vibrations, and thus be productive of sound. Birds, which take a large quantity of air into their capacious receptacles, are remarkable for the strength and copiousness of the sounds they produce. Mammalia present great varieties in the compass of their voice, from the roaring of the lion to the mere blowing of the whale. Even reptiles possess a kind of voice, as is exemplified in the croaking of the frog, and the hissing of the serpent.

In the exercise of no function is the superiority of man more strikingly displayed than in the admirable manner in which he uses his organs of voice in the production of vocal and articulate sounds. We shall first examine the mechanical construction of the instruments employed, and then consider the result of their action. It is principally during expiration that sound is produced. In the lungs we have reservoirs of air, capable of receiving a larger or smaller quantity, according to circumstances, and from which it can be propelled by the action of the muscles of expiration with an adequate force. The air is impelled along the tube named the trachea or windpipe, at the top of which there is placed a complicated apparatus called the larynx, where it is modulated into sound. The sound is then sent through the mouth, and by the tongue, the palate, the teeth, the lips, &c., it is converted into articulate speech, or it is directed through the nostrils, when a peculiar modification is effected.

The windpipe is composed of from 18 to 20 elastic cartilaginous rings. For about a fourth of the circumference it is deficient of cartilage posteriorly, where it is in contact with the gullet. These rings are connected with each other by dense, somewhat elastic membranes, and lined internally with soft mucous membrane, continuous with the lining membrane of the mouth and nostrils. This tube admits of being lengthened and shortened. One set of muscles extended from the chest to the larynx shorten it; another set between the lower jaw and larynx lengthen it. There are also transverse muscular fibres, which stretch across from tip to tip of the cartilaginous rings, whereby the diameter of the tube is diminished on the cessation of the action in the fibres; it is restored to its former state by elasticity. Had the rings been formed of cartilage round the whole circumference, no such variation of diameter could have been effected.

By the movements of the head and neck the length of the trachea is also varied. Singers may be observed to elevate the neck, and carry the head backwards, so as to stretch the windpipe, or incline the head and neck forwards, for the purpose of shortening it, according to the pitch of voice they wish to produce.

It will thus appear that the trachea possesses the properties of the long and short, the wide and narrow tubes of such a wind instrument as the organ. The larynx, to the influence of which the air is next subjected, is composed of five cartilages, three single, and a pair. The largest in the adult male, unless overloaded with fat, forms a conspicuous projection at the upper part of the neck. The apple is fancifully said to have stuck in Adam's throat opposite its most projecting portion, which is therefore called Pomum Adami. The form of this cartilage suggesting the idea of a shield, it is termed thyroid. The next in size has been compared to a ring, and therefore called cricoid. A pair of small cartilages form together a resemblance to the spout of a pitcher; hence the name arytenoid has been applied to them. Over the glottis, or narrow orifice through which the sound issues, the fifth cartilage is placed, which, from its situation, is named epiglottis.

The thyroid cartilage consists of a projection in front, and two sides, terminating superiorly in two processes, by which it is connected to the bone of the tongue: inferiorly, it is articulated by two processes with the cricoid. As its name implies, it serves as a shield to the parts placed behind it. At the same time several muscles are attached to it, to which we shall have occasion to refer. The cricoid is narrow in front, but becomes much enlarged posteriorly; it forms a complete ring,—the only part of the air passages which is thus completely surrounded; it serves as a fixed point both for the larynx and windpipe, and as an insertion to several important muscles. The arytenoids are two small triangular pyramids articulated with the base of the cricoid by an universal joint. The surface of the joint in the arytenoid is a shallow concavity resting upon a small corresponding convexity of the cricoid, so as to admit of motion in every direction. Stretching from the base of each to the thyroid cartilage, are two ligamentous strings, named vocal cords, the attachment to the thyroid being the fixed point; between them is the chink termed the glottis, where the air is converted into sound. A little above the cords there are two folds of the lining membrane, termed the false vocal cords, with a small lenticular pit interposed, termed the ventricle of the larynx. In apes, monkeys, and baboons these ventricles are exceedingly large, which has been given as the reason why they cannot speak,—a reason probably as true as that given by the negroes, who believe that they will not speak lest they be forced to work. By the movements of the arytenoid cartilages the cords are rendered tense or relaxed, and the glottis is widened or narrowed.

The muscles which command these movements are the following:—Two pairs arise from the cricoid, to be inserted into the base of each arytenoid; a third pair stretches from the thyroid to be fixed also to their base; and a single muscle crosses from the one arytenoid cartilage to the other. One pair of crico-arytenoid muscles, from their position, are named posterior; the other lateral. The posterior are comparatively large and powerful muscles; by their action they pull back the arytenoid cartilages, and separate them from each other, whereby the cords are put on the stretch, and the vocal aperture or glottis is widened. The lateral draw them aside and forwards, so that the glottis is widened as before, but the cords are relaxed. The thyro-arytenoid muscles cause the arytenoid cartilages to approximate each other, and draw them forwards, whereby the glottis is narrowed, and the cords relaxed. And lastly, the fibres which stretch from one arytenoid cartilage to the other consist of transverse and oblique filaments, so that their motions are performed with greater steadiness and precision than if they had all been parallel to each other. These fibres constitute the arytenoid muscle, which by its action brings the two little cartilages together, and closes the glottis.

We thus perceive that by the action of these seven muscles the vocal cords can be tuned to the proper pitch by different degrees of tension, and the vocal orifice enlarged or diminished, so as to admit also of proper tuning. Here we see combined the properties of both the stringed and wind instrument. To a person unaccustomed to reflect upon the nicety, ease, and precision of muscular action, it may appear strange that these seven little bundles of flesh should be capable of producing such wonderful results, in effecting the almost infinite tones of voice, not only under the command of the will, but likewise in accordance with the feelings and passions of the mind. It will be less strange when it is considered that they are capable of acting with different degrees of force, with different degrees of velocity, and to different degrees of extent; for they may contract to the tenth, the hundredth, or the thousandth part of an inch, or they may act together in various combinations. For instance, let us take three, the two posterior crico-arytenoid and the arytenoid: the pair will draw the two arytenoid cartilages backwards, and stretch the cords, but they will be prevented from separating them, by the arytenoid muscle being at the same time in action, so that the cords will be rendered tense, and the orifice kept narrow. Even each muscle of a pair may act alternately with its fellow, so as to keep one string in a greater degree of tension than the other. Seeing, then, the innumerable powers and capabilities of these organs, the wonder is lessened, but the admiration is increased, that a little instrument like this should be adequate to all the tones of every language, and of every shade of passion; should furnish such an inconceivable variety, so that every individual of the human race can easily be distinguished by the tone of his voice.

The epiglottis is of a parabolic form, its base fixed to the root of the tongue; it is of softer cartilage than the others, mixed with dense fibres, and has great elasticity. It is somewhat convex above and concave below. By its own elasticity and the elasticity of its attachments in a state of rest, it is constantly raised, so as to preserve a free passage for the air. It may be considered as the watchful guardian of the passage to the lungs. It is covered, like the neighbouring parts, with the common mucous membrane, but here supplied with nerves which impart to it great sensitiveness; so that on the contact of any solid, fluid, or gaseous substance which ought not to enter the air-tube, the alarm is instantly sounded, and the sympathetic action of several neighbouring organs are called into play; the tongue recedes backwards, the larynx is elevated, and the entrance to the air-passage completely closed, so that the contraband article is effectually excluded. If the finger be placed upon Adam's apple, and an effort made to swallow, the larynx will be found instantly to start upwards; the tongue will also be found to press backwards, in order to produce this effect. Occasionally, however, it is taken off its guard, and a drop of fluid or a crumb of bread slips past it, and then gets into what is called the wrong throat. The alarm is now extended to the muscles of expiration; they are powerfully thrown into action; the air is expelled from the lungs by a succession of explosive discharges, constituting coughing, till the intruder is dislodged. By its elasticity, and by regulating the size of the orifice, it is capable of modifying the sound already formed by the glottis.

Let us now glance at the apparatus by which the sound is converted into articulate speech. It may escape either through the mouth or by the nostrils. On looking into the mouth, the opening will be seen into the fauces or throat, which is a kind of common vestibule, from whence there are two openings downwards, the anterior to the windpipe, the posterior to the gullet; two lateral openings leading to the drums of the ears; two upwards and forwards to the nostrils, and one forwards to the mouth. Over the opening to the mouth, a fleshy curtain will be seen to hang down, named the soft palate, from the centre of which is appended the pap of the throat. By appropriate muscles this curtain is capable of being raised, so as to close the posterior or internal orifices of the nose, or it may be brought down, and, along with the root of the tongue, shut the mouth at the back part. These passages may thus be more or less partially or completely closed, as may be required.

The tongue is a curiously constructed instrument. As every one knows, it is principally composed of fleshy or muscular fibres, which run in almost every direction. At its root it is attached to a bone, having some resemblance to the Greek letter υ, therefore called the hyoid bone. This bone is connected with the thyroid cartilage, and on each side with one of the bones of the skull. It not only affords insertion to several muscles, but gives a greater degree of firmness and stability to the tongue, from the great number of muscles connected with the tongue and hyoid bone. The tongue may be altered in its length, breadth, and thickness; it may be variously folded, coiled, and inflected; and, in the twinkling of an eye, it may be carried upwards or downwards, forwards or backwards, or to either side. The apex may be darted out of the mouth with more rapidity than the sight can follow it, and then, with the same rapidity, drawn back in a straight line, or coiled or variously folded. By the same powers the whole tongue may be made elastic, and, when put in motion by the air from the lungs, may be made to vibrate. The varieties in force, velocity, extent, and combinations of the motions of the tongue, owing to the power possessed of distributing to the whole or any given part nervous energy in various degrees of quantity, intensity, rapidity, and duration, render its motions truly astonishing; and yet, independently of all these motions, by which it assists in sucking, deglutition, mastication, and speech, its structure is such as to admit of the distribution of glands and nervous papillæ, so as to render it subservient to secretion, to constitute it a delicate organ of touch, and the principal organ of taste. By the various forms which the tongue assumes, it modulates the sound as it passes along; or it changes the sound still further by more or less obstructing and retarding it; or by striking the back part of the palate with its root, or the anterior part of the palate or teeth with its tip, it altogether arrests the sound, and thus produces different forms of articulate speech; and, *lastly*, when the sound is about to issue forth, it again becomes subject to the influence of the lips, which, under the control of all the combinations and modifications of no less than twenty-three different muscles, assume an incalculable variety of forms, and combining their effects with those preceding, furnish means of expression next to inexhaustible.

But the sound, instead of being sent through the mouth, may be transmitted through the nostrils, and thus become subjected to the influences of the soft palate which commands and regulates the posterior orifices of the nose, or, by the movements produced by the muscles of the external orifices, be subjected to other modifications before it finally makes its escape.

All the surfaces along which the sound is transmited are moistened with secretions, which aid and modify it to a certain extent; for, if they are deficient in quantity, or vitiated in quality, the voice is affected, as in a common catarrh. All these parts of this admirable instrument of vocal and articulate sound are brought into co-operation and attuned with just concordance through the medium of the nerves, under the control and direction of the mind.

It is, indeed, an admirable piece of machinery, possessing all the powers and properties both of the wind and stringed instrument, far surpassing in compass, flexibility, and expression, every musical instrument of human invention, even when played upon by another masterly instrument, the human hand, under the direction of the human mind, however excellent the original taste, or however high the cultivation of that mind may be.

Every perfect human being at birth is capable of acquiring every tone and modification of expression of every language that ever has existed, now does, or ever can exist upon the face of the earth, with all their various inflections and accents. Nay, so infinitely various are these original capabilities, that of the many millions of millions of the human race, probably no two individuals have ever happened to employ them exactly alike, even in the use of the same language; so that every individual of mankind is characterized by his voice. In the course of time, the different parts fall into certain habits of action, so that the original capabilities are in a great measure lost, the organs becoming limited to the expression of the language in which they have been educated, so that many of the sounds and inflections of other languages in advanced life become difficult and almost impossible to be acquired. There are certain tones of the voice which are indicative of the feelings and of the passions and emotions of the mind, as those of pleasure and pain, of joy and grief, of satisfaction and resentment, which are instinctive, and universally understood by the savage and the civilized. While the acquired sounds express the conceptions of the mind, they are often tinged by the emotions and passions.

The most excellent musical performers with the voice must combine both the power of conceiving the music (possess the ear), and the most complete control and command of the instruments (have the voice), so as to execute the performance. However perfect the instrument may be, without the mind to play upon it, it is useless as an organ of music and as an organ of speech. The examination of the organs of voice will not teach us whether they had been employed in expressing the language of the civilized European or savage New Hollander. It is therefore useless to inquire why the lower animals cannot speak as man does, notwithstanding their organs approach those of man closely in conformation; yet the sounds which they utter adequately express their conceptions and feelings, and are sufficiently well understood by each other.

Respiration of different Gases.—On the discovery of the different gases, their effects were tried upon respiration. The greater number of the gaseous substances known cannot be inhaled in their pure unmixed state; others are capable of being so. Gases are therefore divided into respirable and irrespirable.

The respirable gases are nitrogen, hydrogen, oxygen, nitrous oxide, and carburetted hydrogen. The two first appear to be negative in action, the effects appearing to result merely from the exclusion of atmospheric air. As the respiratory movements, however, and the distension of the cells of the lungs, even with these gases, will favour the transmission of blood through the lungs, where, at the same time, it cannot undergo the necessary conversion from venous to arterial, and consequently the dark-coloured blood being sent in greater quantity to the brain and the rest of the system, death will sooner take place than in mere suspension of respiration. When animals are made to breathe pure oxygen, care being taken at the same time to withdraw any carbonic acid which may be formed, at first they appear but little affected, but in time they become uneasy, symptoms of distress are shewn, and finally life is destroyed. On examination after death, there are found evidences of inflammation of the lungs having been excited; so that although this gas in a pure state may be respired longer than any other, yet ultimately it proves fatal. The most interesting account we have of the effects from the respiration of nitrous oxide is given by Sir H. Davy, who was the first to shew that it was by no means so deleterious as had been previously believed, since he proved that it might be inhaled with safety, and that the respiration of it produced very striking and remarkable effects. It has frequently been breathed since, and now affords one of the most common displays in a popular course of lectures. The following striking account of the effects of this gas is given by Sir H. Davy:—

"On December 26th I was inclosed in an air-tight breathing-box, of the capacity of about nine cubic feet and half, in the presence of Dr Kinglake.

"After I had taken a situation in which I could, by means of a curved thermometer inserted under the arm, and a stop-watch, ascertain the alterations in my pulse and animal heat, 20 quarts of nitrous oxide were thrown into the box.

"For three minutes I experienced no alteration in my sensations, though immediately after the introduction of the nitrous oxide the smell and taste of it were very evident.*

"In four minutes I began to feel a slight glow in the cheeks, and a generally diffused warmth over the chest, though the temperature of the box was not quite 50°. I had neglected to feel my pulse before I went in; at this time it was 104, and hard; the animal heat was 98°. In ten minutes the animal heat was near 99°; in a quarter of an hour 99.5°, when the pulse was 102, and fuller than before.

"At this period 20 quarts more of nitrous oxide were thrown into the box, and well-mingled with the mass of air by agitation.

"In twenty-five minutes the animal heat was 100°, pulse 124. In thirty minutes 20 quarts more of gas were introduced.

"My sensations were now pleasant; I had a generally diffused warmth, without the slightest moisture of the skin, a sense of exhilaration similar to that produced by a small dose of wine, and a disposition to muscular motion and to merriment.

"In three quarters of an hour the pulse was 104, and animal heat not 99.5°; the temperature of the chamber was 64°. The pleasurable feelings continued to increase, the pulse became fuller and slower, till in about an hour it was 88°, when the animal heat was 99°.

"20 quarts more of air were admitted. I had now a

* The nitrous oxide was too diluted to act much; it was mingled with near 32 times its bulk of atmospheric air.

great disposition to laugh; luminous points seemed frequently to pass before my eyes; my hearing was certainly more acute, and I felt a pleasant lightness and power of exertion in my muscles. In a short time the symptoms became stationary; breathing was rather oppressed, and, on account of the great desire of action, rest was painful.

"I now came out of the box, having been in precisely an hour and quarter.

"The moment after, I began to respire 20 quarts of unmingled nitrous oxide. A thrilling, extending from the chest to the extremities, was almost immediately produced. I felt a sense of tangible extension highly pleasurable in every limb; my visible impressions were dazzling, and apparently magnified; I heard distinctly every sound in the room, and was perfectly aware of my situation.* By degrees, as the pleasurable sensations increased, I lost all connexion with external things; trains of vivid visible images rapidly passed through my mind, and were connected with words in such a manner as to produce perceptions perfectly novel. I existed in a world of newly connected and newly modified ideas. I theorised; I imagined that I made discoveries. When I was awakened from this semi-delirious trance by Dr. Kinglake, who took the bag from my mouth, indignation and pride were the first feelings produced by the sight of the persons about me. My emotions were enthusiastic and sublime; and for a minute I walked round the room perfectly regardless of what was said to me. As I recovered my former state of mind, I felt an inclination to communicate the discoveries I had made during the experiment. I endeavoured to recall the ideas; they were feeble and indistinct. One collection of terms, however, presented itself; and with the most intense belief and prophetic manner, I exclaimed to Dr Kinglake, "*Noth-*

* In all these experiments, after the first minute, my cheeks became purple.

ing exists but thoughts!—the universe is composed of impressions, ideas, pleasures, and pains!"

"About three minutes and a half only had elapsed during this experiment, though the time, as measured by the relative vividness of the recollected ideas, appeared to me much longer.

"Not more than half of the nitrous oxide was consumed. After a minute, before the thrilling of the extremities had disappeared, I breathed the remainder. Similar sensations were again produced; I was quickly thrown into the pleasurable trance, and continued in it longer than before. For many minutes after the experiment I experienced the thrilling in the extremities; the exhilaration continued nearly two hours. For a much longer time I experienced the mild enjoyment before described connected with indolence; no depression or feebleness followed. I ate my dinner with great appetite, and found myself lively and disposed to action immediately after. I passed the evening in executing experiments. At night I found myself unusually cheerful and active; and the hours between eleven and two were spent in copying the foregoing detail from the common-place book, and in arranging the experiments. In bed I enjoyed profound repose. When I awoke in the morning, it was with consciousness of pleasurable existence, and this consciousness more or less continued through the day."

He tried it on other occasions with similar results. It was also breathed by several other persons under his superintendence; and though generally found to produce pleasurable excitement and hilarity, without being followed by subsequent depression, yet in some instances, especially in females, disagreeable effects were experienced, such as a tendency to fainting and hysterical affections. The excitement from nitrous oxide displays itself differently in different persons: Some are thrown into a state of immoderate laughter, which to the spectators is the more absurd, as there is no apparent cause for it. Very often the bystanders sympathize, and the laughter becomes universal. In other instances most vigorous and active dancing is had recourse to; while in others no small degree of pugnacity is displayed. From experiments performed upon the lower animals, it appears that life is prolonged by the respiration of it longer than where they breathe pure hydrogen or nitrogen, which apparently act by excluding oxygen. Still, in a short time life is destroyed by it, circulation and respiration being thrown into the most tumultuous action previous to death. Carburetted hydrogen having been found to be destructive of animal life, its effects were also tried for the first time, on his own person, by Sir Humphry Davy. These will be best shown by his own statement:—

"Emboldened by this trial, in which the feelings were not unlike those I experienced in the first experiments on nitrous oxide, I resolved to breathe pure hydrocarbonate.

"For this purpose I introduced into a silk bag four quarts of gas nearly pure, which was carefully produced from the decomposition of water by charcoal an hour before, and which had a very strong and disagreeable smell.

"My friend, Mr James Tobin jun., being present, after a forced exhaustion of my lungs, the nose being accurately closed, I made three inspirations and expirations of the hydrocarbonate. The first inspiration produced a sort of numbness and loss of feeling in the chest and about the pectoral muscles. After the second inspiration, I lost all power of perceiving external things, and had no distinct sensation except a terrible oppression on the chest. During the third expiration, this feeling disappeared, I seemed sinking into annihilation, and had just power enough to drop the mouth-piece from my unclosed lips. A short interval must have passed, during which I respired common air, before the objects about me were distinguishable. On recollecting myself, I faintly articulated, "*I do not think I shall die.*" Putting my finger on the wrist, I found my pulse thread-like, and beating with excessive quickness.

"In less than a minute I was able to walk, and the painful oppression on the chest directed me to the open air.

"After making a few steps, which carried me to the garden, my head became giddy, my knees trembled, and I had just sufficient voluntary power to throw myself on the grass. Here the painful feeling of the chest increased with such violence as to threaten suffocation. At this moment I asked for some nitrous oxide. Mr Dwyer brought me a mixture of oxygen and nitrous oxide. I breathed this for a minute, and *believed* myself relieved. In five minutes the painful feelings began gradually to diminish. In an hour they had nearly disappeared, and I felt only excessive weakness and a slight swimming of the head. My voice was very feeble and indistinct. This was at two o'clock in the afternoon.

"I afterwards walked slowly for about half an hour with Mr Tobin jun., and on my return was so much stronger and better as to believe that the effects of the gas had disappeared, though my pulse was 120, and very feeble. I continued without pain for near three quarters of an hour, when the giddiness returned with such violence as to oblige me to lie on the bed; it was accompanied with nausea, loss of memory, and deficient sensation. In about an hour and half the giddiness went off, and was succeeded by an excruciating pain in the forehead and between the eyes, with transient pains in the chest and extremities.

"Towards night these affections gradually diminished. At ten* no disagreeable feeling except weakness re-

* I ought to observe, that between eight and ten I took, by the advice of Dr Beddoes, two or three doses of diluted nitric acid.

mained. I slept sound, and awoke in the morning very feeble and very hungry. No recurrence of the symptoms took place, and I had nearly recovered my strength by the evening."

Thus, of the five gases which can be received into the lungs in an unmixed form, two, nitrogen and hydrogen, act by excluding oxygen. Pure oxygen can be respired longer than any other, but ultimately induces fatal derangement. Nitrous oxide causes a high state of excitement, and if persisted in, soon causes death, apparently from over excitement; and carburetted hydrogen is one of the most direct sedatives to which the body can be exposed. These gases, when presented to the extensive surface of the air passages, where absorption is readily effected, are taken up and carried along with the blood to every part of the body, and speedily exert their influence upon the brain and nervous system. All other gases in an undiluted state cause such a degree of irritation as to produce spasmodic closure of the glottis, and death follows from suffocation; but when mingled with atmospheric air, they may be received along with it, and display their peculiar effects on the system with greater or less intensity, according to their nature and degree of dilution. Thus, carbonic acid, in the small quantity in which it is found in the atmosphere, has no perceptible effect; but when in greater proportion to the air, it displays peculiar poisonous properties; while pure and unmixed it cannot be inhaled.

Asphyxia.—The term asphyxia is applied to that state of apparent death arising from suspension of respiration, and furnishes many facts which shew the absolute necessity of that function. It differs from real death, in there being a possibility of restoring life; but the body can only remain in this state for a very short time, as it soon terminates in actual death. Suffocation may arise from a number of different causes. The respiratory movements of the chest may be prevented by mechanical causes; fluids may accumulate in the chest, so as to prevent the expansion of the lungs; tumours may press on the air passages; or foreign bodies may be lodged at the orifice of the windpipe, so as to obstruct breathing; and in the same way does hanging produce its effects. It has been stated that the entrance to the windpipe is endowed with a remarkable irritability, whereby, on the contact of all solids and fluids, and of gaseous substances, with the few exceptions mentioned, it is instantly closed. Immersion in any fluid, as in water, destroys life, by inducing this spasmodic closure. Carbonic acid and other irritating causes act in the same way. Asphyxia may also be produced by the condition of the brain and nervous system being such as to put a stop to muscular movements necessary for carrying on the process of breathing. Thus, apoplexy, or injuries of the brain from falls, blows, &c., may cause it. Various poisons operate by their direct effect upon the brain and nerves, implicating and suspending the respiratory movements. In all these instances the train of phenomena which takes place is similar, the residual air in the lungs being soon exhausted. The dark-coloured blood sent by the right ventricle of the heart to the lungs does not undergo the necessary changes, —it paralyzes the capillary vessels. A less quantity is transmitted to the left ventricle, and that too the dark venous blood, which being propelled to the different parts of the system, is incapable of supporting the functions, and especially deadens the brain and nervous system, first producing giddiness, and confusion of thought; insensibility follows, and the scene is generally closed in convulsions. From respiration being stopped, the blood does not obtain a ready entrance into the chest. It accumulates in the veins, producing lividity of the face, and protrusion of the eyeballs. In suffocation the lungs are the first which die; next the brain; and last of all the heart.

The function of breathing cannot be suspended more than four or five minutes with any chance of restoring li[illegible] There are, however, instances where criminals have [illegible] hung for the legal period, which at one time was limited in Scotland to an hour, and the functions again restored. Several years ago a woman underwent her sentence in Edinburgh. Her body was delivered to her friends, and placed in a cart, in order to be conveyed to some distance in the country. On the road the friends entered a public-house for refreshment. On coming again to the cart, to their astonishment they found their executed relation restored to life. She afterwards for many years sold salt through the streets of Edinburgh, under the name of "half-hanged Maggie Dickson."

In fainting, where the circulation is suspended, there is apparent death, as in asphyxia, but the dark-coloured blood does not circulate so as to act as a poison. It may continue so long that preparations have been made for the burial of the body, and yet resuscitation take place. It has even been stated, and is a matter of general popular belief, that interment has been carried into effect on persons in this state, affording foundation for the concocters of stories of the horrible and awful. Now, in the above case of "half-hanged Maggie," it is most probable that when she was about to be cast off, she fainted, and that therefore excitability remained. It is also probable that the jolting of the cart conduced to her restoration. Drowning produces death by the water causing a spasmodic closure of the glottis, so that there is little or no hope of restoring the functions after a few minutes immersion. But there are instances where persons have been under water for a much longer period, and yet revived. These admit of the same explanation as similar cases from hanging, for fainting has occurred at the moment of immersion.

Carbonic acid being a product of many operations carried on in nature, and in the arts, frequently produces fatal effects by either of its modes of action, that is, by causing suffocation, or acting as a narcotic poison. Being heavier than atmospheric air, it occupies the lowest situation. It sometimes accumulates in old wells and mines, and is known to the miner under the expressive name of choke-damp. It is also found in caves, as in the Grotto del Cane in Italy. The celebrated valley of the Upas tree in Java is destructive of animal life from containing this gas. It is given off during fermentation; hence the danger of entering a brewer's vat immediately after the liquor is drawn off, as the vessel remains for sometime filled with it. As has been shewn, it is discharged from the breath during respiration. In crowded and ill-ventilated apartments it sometimes accumulates in a quantity to prove noxious, causing drowsiness and averseness to action. The victims in the black hole of Calcutta seem to have been destroyed by it. It is generated during combustion; hence the danger of leaving charcoal or cinders unextinguished in sleeping chambers or ill ventilated rooms, the neglect of which has not unfrequently produced fatal consequences. Narcotic poisons, such as opium, ardent spirits, &c., act by deadening the sensibility of the brain and nerves: the muscular movements essential to breathing are slowly and imperfectly performed; the necessary salutary changes are not produced on the blood; it mounts to the brain, and the evil is aggravated so as soon to place the patient beyond the possibility of recovery.

Means of restoring Animation.—From what has just been stated, not a moment ought to be lost in having recourse to proper measures with the view of restoring animation. In hanging, death may be caused in two ways. The bones of the neck may be dislocated, when death instantly and inevitably takes place; or suffocation is produced, inducing asphyxia. In drowning, apparent death may arise from two causes, 1*st*, the person may be submersed in the water while respiration is going on; or 2*dly*, fainting may occur previous to immersion. The chance of recovery is very different in these two conditions, and therefore it is very important to distinguish between them when a person is taken out of the water.

In the former case, the face appears swollen and livid, especially the lips and ears. There is usually frothy mucus about the mouth and nostrils, and the rest of the body is generally pale. In the latter condition, there is paleness of the face, without marks of struggle in the features or in the neck, and the countenance appears tranquil, as in a deep sleep. The first circumstance to be attended to is to place the body in as favourable a posture for the process of breathing as possible. With this view, it is to be placed with the head and upper part somewhat elevated. The neck is instantly to be laid bare, and all bandages surrounding the chest immediately cut. As the glottis is most likely still in a state of spasm, the larynx must be drawn downwards; at the sametime the shoulders, ribs, and breastbone must be elevated, that the residual air in the lungs may dilate, and a fresh portion be drawn in; the respiratory movements of the chest are as far as possible to be imitated.

If these fail, the lungs should be inflated, either with bellows or by blowing air with the mouth through the nostrils or mouth, care being taken to keep the larynx drawn down, that the glottis be kept open, and also gently pressed upon the gullet, that air may be prevented from passing into the stomach. During inflation means ought to be adopted for simultaneously enlarging the chest, for if this be neglected, and the air be forced into the cells while the lungs are compressed by the walls of the chest, the delicate air tubes may be ruptured, and the patient placed beyond the possibility of recovery.

From the important relations between the skin and the lungs, the body being stripped, which it ought to be as soon as possible, it is to be rubbed with hot flannels, and the palms of the hands and the soles of the feet diligently brushed. In order to arouse irritability, stimulating vapours may be applied to the nostrils; and, with the view of relieving the brain, the jugular vein may be opened. If the temperature be reduced, means must be had recourse to for imparting heat. Bags filled with warm sand, salt, sawdust, &c., or bottles filled with hot water, wrapt up in cloth, may be applied to the soles of the feet, pit of the stomach, &c. Frictions with hot flannel are at the same time to be persisted in. The warm bath, on physiological principles, to say the least, is of very doubtful efficacy; for though in this way heat be readily imparted, still the beneficial influence of the air upon the skin is lost, and other important means for resuscitation cannot be so well applied at the same time with it. If by these means we happily succeed in the re-establishment of respiration, we must not intermit our attentions. For the first blood transmitted by the heart being only imperfectly purified, may paralyze the brain, induce stupor, and endanger life. The patient must be kept roused, a moderate bleeding may be useful, and he must be assisted and kept walking about till the vital functions are again fairly established. When asphyxia has been produced by causes which do not at the same time carry off the heat of the body, as from exposure to carbonic acid, dashing cold water upon the face may be of advantage. Where dangerous symptoms arise from poisons, such as from opium and other narcotics, there is generally time for procuring professional assistance, when measures will be adopted which can only be properly carried into effect by professional hands, or had recourse to under the immediate superintendence of the professionally instructed.

CHAPTER III.

DIGESTION.

A General Account of the Changes which the Food undergoes in the Digestive Organs—Man a Cooking Animal—Food assimilated to the Temperature of the Body in the Mouth—Teeth, their Structure and Use in various Animals—The Teeth of Man, their Form, Number, and Structure—Why there are two Sets—Motions of the Jaw—Saliva, Composition and Use of—Deglutition—General view of the Alimentary Canal—Stomach—Duodenum—Small Intestine—Large Intestine—Liver—Spleen—Pancreas—Organs of Digestion in Carnivorous Animals—in Ruminants—in Birds—Digestive apparatus of Man adapted to a greater variety of Food than that of any other Animal—Animal Food, and its proximate principles—Vegetable Food, and its proximate principles—One or other most suitable to different climates—Concentration, Variety, Consistence, and Quantity influence the Digestibility of Food—Condiments, Salt, Acids, Bitters, Astringents, Aromatics—Hunger and Thirst—Chymification—Gastric Juice—Its peculiar powers—Chylification—Biliary, Pancreatic, and Intestinal Secretions—Chyle absorbed, and conveyed through intricate channels, becomes gradually assimilated to, and converted into perfect Blood—Last efforts for the Abstraction of Nourishment—Drinks—Several substances introduced into the Circulation from the Alimentary Canal without being changed.

The continual expenditure which goes on in the body, from the fluids dissipated on the surface of the skin and in the breath, the discharges that take place in urine, and other secretions, and the constant changes occurring in the materials of every part of the body, demand fresh matter to compensate for the loss. During the whole existence of all living bodies, a perpetual succession of matter occurs; the old is discharged, and new taken up in its place. Plants being fixed to a single spot, immediately receive into their systems the materials on which they subsist, as it is presented to them, without its being previously subjected to alteration; while animals, on the other hand, are furnished with apparatus more or less complicated, whereby their aliment is acted upon so as to fit it for being conveyed into their systems. The organs which effect these changes, and which adapt it to the constitution of the animal, are the organs of digestion.

No organs in the body more distinctly shew the admirable adaptation of structure to circumstances, according to the rank of the animal, the nature of its food and habits. For example, carnivorous animals, subsisting upon aliment highly nutritious in proportion to the bulk, and of easy conversion into an appropriate animal fluid, possess a simple apparatus, and of comparatively small size; while in herbivorous animals, living on food which yields no great quantity of nourishment, and that distinct from animal substance, it requires to be exposed for a considerable length of time to the influence of capacious and complicated machinery, in order to become animalized. The cavity of the abdomen, or belly, which is occupied chiefly by the digestive organs, is accordingly large in the latter, but much smaller in the former.

In the view which we shall take of the process of digestion, we shall follow the successive changes which take place, and the manner in which they are brought about, from the first introduction of food into the mouth, till it is converted into arterial blood in the lungs.

In the mouth the food is subjected to the mechanical action of the teeth, and is mixed with the secretions of several neighbouring glands. It is then transferred to the stomach, along the gullet. In the stomach it remains for some time, where it is subjected to the action of the fluids of that organ, and converted into a pultaceous mass, termed chyme. This gradually passes into a cylindrical canal, the intestine, in the first portion of which it meets with the bile from the liver, and with a fluid furnished by another large gland called the pancreas. After this, a white milky-like fluid, the chyle, is separated from the general mass, and is drunk up by the innumerable vessels which open on the surface of the intestine as it passes along. Having traversed the long winding canal, the smaller intestine, and the nutritious particles having been absorbed, the mass is next transferred to the large intestine, termed the colon, where the last efforts are made to abstract nourishment from it; and lastly, the remainder, when time and opportunity are convenient, is rejected. The chyle, on being taken up by the absorbent vessels, opening on the internal surface of the intestinal canal, is conveyed by these vessels through a number of small glands, after which it is collected into a receptacle, from which it is conveyed by a tube through the chest, and poured into the great veins, as they are proceeding to the right side of the heart. From the commotion to which it is exposed by the concussion of the right side of the heart, it is intermixed thoroughly with the venous blood, and propelled to the lungs, where it is perfected into arterial blood.

From the examination of the organs of digestion of man, attempts have been made by some to prove that he was intended to be carnivorous; others contend for his being frugivorous; while numerous facts may be brought forward from the same source to shew that he was intended to be a cooking animal. It is very evident, that the great Author of his being intended that this function should be exercised to a certain extent, in connexion with his intelligence as a rational creature. It is not only a superficial and partial view, but unfair and untrue, to consider man's character as dependent upon his mere material organization. He has been blessed, it is true, with an admirable material structure, but with a structure associated with a rational spirit. While life exists, the relations between them are most close and intimate, and must continue to be so till dissolved by the hand of death. They mutually act and react upon each other; whatever affects the one makes a greater or less impression on the other. As they are thus mutually dependent, so do we find them beautifully co-operating together. The history of mankind tends to prove, that wherever man is found in a low and savage state, traces appear of his having fallen from a more civilized condition; and however degraded his savage condition may be, there is no instance of his confining himself in his food entirely to the state in which it is furnished by the hand of nature. He subjects it to processes of preparation before he introduces it into his organs of digestion. If man were not a cooking animal; did he not exercise his intelligence in the preparation as well as in the selection of his food, most of the fairest parts of this earth would be to him totally uninhabitable for by far the greater part of the year, and others constantly so throughout the whole year. Many substances, which are altogether unfit as articles of food, nay, even highly poisonous, are rendered grateful and nutritious by preparation. The raw potato may serve as an example, or the root of the deadly poisonous plant Jatropha Manihot, which, on being exposed to heat, has the poison dissipated, or by preparation furnishes the Tapioca or Cassava of commerce, frequently employed for the diet of invalids.

To nothing is man so much indebted for his comforts, his luxuries, and even his very subsistence, as to the mastery he has obtained over heat. It not only furnishes him with the gigantic power of the steam-engine, reduces metals to his subjection, supplies him with the most deadly weapons of offence and defence, and in a thousand other ways contributes to supply his wants and necessities, but it also prepares an endless variety of food for him, which without its aid would be altogether unfit as such; while it alters other substances, so that they are rendered both more nutritious and more easily acted upon by his organs of digestion.

Man, in proportion to his size, has the smallest mouth of any animal: in every respect it is beautifully and symmetrically formed. In the mouth the food is subject to the following changes: it is assimilated to the temperature of the body; the teeth, by trituration, reduce it to a minute state of mechanical division, and when it consists of different substances intermix them together; and by insalivation it is mixed with fluids, which at the time are poured abundantly into the mouth.

Assimilation of Temperature.—The mouth possesses great sensibility to temperature,—much greater than the stomach,—whereby it is enabled to judge of the proper temperature of substances before they are transmitted to that organ. Had the reverse been the case, materials might have been transferred to the stomach while scalding hot. But as it is, a person, for example, eating hot soup, will sometimes prefer hurrying it over into the stomach, rather than do anything so unseemly as reject it out of the mouth, knowing that its high temperature will be more tolerable there. If the temperature of the morsel of food be below that of the body, it gradually obtains heat, so as to be assimilated to it.

Trituration.—The teeth present great diversities in form, number, situation, and the purposes to which they are subservient in the different tribes of animals,—so much so, that naturalists have selected them to furnish characters for the distribution of mammalia into orders and families. Some of the mammalia are without teeth, as the ant-eaters and armadilloes. In some of the whale tribe, they consist of a series of horny plates proceeding from the upper jaw, well known under the name of whalebone. These plates are placed vertically, present sharp edges externally, which overlap each other like tiles, their internal edges being furnished with long hairlike fringes, which serve as sieves whereby they entangle the food on which they subsist.

The whole class of birds are devoid of teeth. Their bills are variously modified for seizing or tearing their food; but where it is necessary that it should be subjected to trituration, their stomach or gizzard is furnished with powerful muscular apparatus, lined with a hard insensible horny covering; and in order to aid in the reduction of the food, they instinctively swallow pieces of quartz, and other hard substances.

The teeth of venomous serpents present the most deadly weapons with which animals are furnished. The poison-fangs are of a curved form. When the animal is tranquil, they are retracted by an elastic ligament, like the claws of a cat; but when it is about to inflict a wound, they are erected by a muscle; they are also provided with a tube, opening by a fissure, through which the poison, secreted by a peculiar gland, is injected into the wound.

Teeth in carnivorous animals, such as the lion, tiger, &c. are dreadful weapons: so are they in the wild boar. The elephant employs them as means of defence. In the narwhal or unicorn, a single tooth only is in general developed, its fellow being rudimental; it is remarkable for its length and spiral form, and has been conjectured to serve as a weapon. These powerful tusks in the elephant, narwhal, and walrus, are only fully developed in the male, the female having them in a rudimentary state. These animals are all gregarious, and the defence of the herd falls principally upon the males, which are thus armed accordingly.

In carnivorous animals, their food not requiring trituration, the teeth are adapted for seizing their prey, for lacerating and tearing it to pieces; they are conical and pointed, and lock into each other, so that their points do not come in contact, and thus preserve their sharpness. In the squirrel, the beaver, rats, mice, &c., there are two long cutting teeth in each jaw, furnished with a thick deposit of enamel anteriorly, but devoid of it posteriorly, the bony portion behind being more easily worn down than the anterior enamel. The edge is preserved in the proper degree of sharpness; they exactly resemble chisels, and although they may be employed for years in gnawing very hard substances, in opening nuts, or in felling forest trees, yet they never become blunted. Besides these chisels, animals of this order are furnished with grinding teeth for properly reducing their food. Granivorous and herbivorous animals are supplied with cutting teeth in both jaws, as in the horse, or they are confined to the lower jaw, as in oxen, sheep, and deer. The former seize upon their food as with two rows of nippers, the latter with the aid of the lips, tongue, and dense gum of the upper jaw, cut the grass close to the ground while browsing in the fields. They possess, besides, a series of excellent grinders, whereby they reduce their food to a minute state of mechanical division, and thus prepare it for being more readily acted upon by the organs to which it has subsequently to be presented.

Man, in proportion to his size, has the smallest teeth of any of the mammalia. In him they form two rows, each tooth being in contact with, and supporting its neighbours; they are also nearly on the same level,—circumstances which distinguish him from those animals, such as the orang outang, which approach nearest him in bodily conformation. In the adult, each jaw contains four cutting teeth in front, next to which are a pair of conical teeth, named the eye or corner teeth, or, from their being conspicuous in the dog, they are called canine, behind which are placed on each side five grinders, the two anterior of which have two points, the three posterior with broad upper surfaces, and more than two points, which lock into corresponding depressions in their fellows of the opposite jaw. There are thus sixteen teeth in each jaw, when complete in both, forming a case of thirty-two beautiful little instruments.

At birth, the teeth have not made their appearance. The mouth is small, but admirably fitted for seizing the nipple, and serving as a sucking instrument; and how well does it perform this duty, without previous tuition! affording one of the many thousand examples in the animal machine, that nothing is left to chance, nothing unforeseen or unprovided for by its Author. Wherever circumstances occur involving new conditions, whenever the necessity arrives, means are at hand ready to start into action to execute the duty, and without previous education, perform the task with that perfectness and precision which characterize all the works of the Creator. As the organs of digestion in the infant gain strength, and become prepared for an alteration of diet, the teeth begin to appear, which they do in succession, commencing with the central incisors of the upper jaw.

Teeth being formed of a substance which does not admit of growth in accordance with the gradual enlargement of the jaw, a principle which nowhere else exists in the body is adopted. Two sets of teeth are furnished, differing in size, number, and some of them in form. The first set consists of four incisors, two canine, and four grinders in each jaw. During the continuance of the first, the second set are in the progress of development. As they enlarge, they press upon the roots of the first, and deprive them of nourishment, so as to cause absorption of the roots. The former, therefore, are shed without the roots. At birth, the bones of the face bear a smaller proportional size to those of the skull than they do subsequently. They rapidly outstrip in growth the bones of the skull, particularly after the seventh year, and continue to increase to the eighteenth or twentieth year. About the seventh year, the second set of teeth, which are larger, begin to supplant the first, and appear in the same order of succession. The two pairs of grinders in each jaw next the canine have no representatives in the first. They are much longer in making up the number, this not being completed till the eighteenth or twentieth year, when the posterior pair of grinders make their appearance, at a time when the owner, if he has not, ought to have arrived at the years of discretion; hence they are termed the wisdom teeth. Some jaws are so small, however, that they cannot contain the full number. Some of the teeth, therefore, remain in the jaw, which, when the others drop out, may make their appearance even in a very advanced period of life, flattering the deluded individual that a renewal of his age is taking place.

The earliest period from which the rudiments of the teeth can be traced is about the fourth month of fœtal life. If examined some time after this, when they can be observed with greater facility, they appear like small sacs, abundantly supplied with blood-vessels and nerves. The inner surface of the little vesicles secretes a peculiar substance, the enamel, which is arranged in a crystallized form, and constitutes the external crust of all that part of the tooth which has to be exposed above the jaw. The cavity within the crust is filled with a pulp composed of blood-vessels and nerves, from which an exceedingly hard bone is formed, so as to fill up the crust; in order to give it support, the fang or root is gradually added. When the tooth bursts through the sac, the remains of the sac are removed by absorption, so that the vessels which formed the enamel are destroyed, consequently there can be no renewal of it, though, according to some, the gum subsequently takes upon it the office of nourishing the enamel.

The bony part of the tooth, composing its centre and root, continues to live and to be supplied with blood and nervous energy. The blood-vessels and nerve in the full-grown tooth are exceedingly minute. They enter by a small hole in the root. The passage becomes enlarged inwards, so as to form a small cavity where the process of nutrition goes on: the nervous twigs are derived from one of the most sensitive nerves of the whole body, the fifth pair; so that when inflammation takes place, swelling being prevented, it is accompanied with such exquisite anguish as no one can form an idea of who has not experienced tooth-ache.

The enamel is an insensible crust, covering the hard but living bone which composes the rest of the teeth. Though insensible itself, it does not prevent the transmission of sensation; for, when the teeth are set on edge, or when they are exposed to cold, they feel, notwithstanding this covering; just as the insensible scarf skin, the nails, or even the hoofs of animals, do not destroy the transmission of sensations, or rather the causes which excite sensations, in the subjacent parts. The crystalline structure is beautifully arranged, in order to resist the friction to which it is exposed. The crystals are longest or the deposit is thickest where most exposed to attrition.

FIG. 11.

This will be best understood by the accompanying wood-cut. In the cutting and canine teeth the crystals are longer at the points and the outer surface *a*, than on the inner surface *b*, while in the grinders they are longest upon their upper surface. The bony part of the tooth is composed of a greater proportional quantity of earthy matter than the other bones of the body; and the enamel, besides differing from bone, in being supplied neither with blood-vessels nor nerves, and in being formed of crystals, differs from bone in composition, by having no cartilage in its constitution.

With respect to external characters, a tooth is divided into the crown, or all that part which is externally exposed; the neck, which is immediately embraced by the gum; and the root or fang, which is inserted into the socket. The incisors, acting like scissors, those of the upper jaw generally overlapping those of the lower, have small roots. The canine, employed in tearing, have large and strong roots: the two first pairs of grinders have two roots agglutinated into one, and the other grinders have from three to four roots.

The manner in which the teeth are supported by the gum, and fixed in the socket, is also deserving attention. The gums not only serve as firm elastic cushions, whereby they rapidly diffuse the force, and powerfully support the teeth when forcibly employed, but by the vascular connexion between them, in part supply them with nourishment. In old age, when the different parts of the body begin to shrink, the gums recede from the teeth, whereby they frequently become loose and drop out, though perfectly sound. By the manner in which the teeth are implanted in the sockets, they are afforded an extensive surface of support. The force is not concentrated at the point, as in the case of a nail thrust into a board, but is uniformly diffused over the whole surface of the fang, as may be seen in the annexed cut, where the fangs of the middle tooth press on a surface, *a a a*, equal to four times that of the crown, *b*; so that supposing the pressure on the crown to be equal to four pounds, being extended over the surface of the fangs, it is reduced to one pound on any given point of the root, and with a similar force upon the sockets.

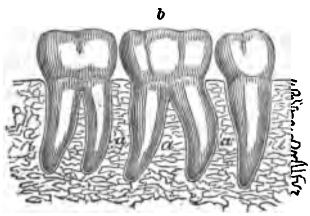

FIG. 12.

In mammalia, the lower jaw alone is moveable. In birds, the upper jaw is moveable in different degrees in different families. In some reptiles, as in the crocodile, both jaws are moveable, the upper moving on the first vertebra of the neck, whereby the mouth can be opened to a great extent. In serpents, the jaws may be opened so as to take in prey of greater diameter than that of their own body. In mammalia which grind their food, the jaw, besides possessing motion upwards and downwards, has also a lateral motion; while in carnivorous animals the hinge motion upwards and downwards alone exists.

Man is distinguished more by the variety than the extent of the motions of his jaw. These consist of six primary movements, viz. upwards and downwards, by which the mouth is opened and shut; lateral motion, from side to side; and motion forwards, whereby the teeth of the lower jaw are carried before those of the upper, and backwards, whereby the jaw is retracted. In order to facilitate the mobility of the jaw, the joint by which it is connected with the skull is double, there being a moveable cartilage interposed between two capsules. As the principal force is required in shutting the jaw, the muscles employed for this purpose are large and powerful. One arises from the temple on each side, and from its situation is named the temporal; it may be seen in action during mastication. Another proceeds from the cheekbone, and runs down towards the angle of the jaw; it may be felt in action by placing the finger a little above the angle of the jaw, and pressing the teeth together. Another is placed opposite to it internally. The fourth, also placed internally, is chiefly employed in the motion forwards. The antagonists to these consist of a pair which extend from the base of the skull to the chin, and of three pairs between the hyoid bone and chin. Though physically weaker than those which shut the jaw, they possess the advantage of a longer lever; still they are not required to exert the same force as those which move it upwards. It is to be recollected that the jaw rarely moves in the direction of the fibres of any of the above muscles, but generally in the diagonal between their different forces, whereby the movements are performed with greater steadiness than they otherwise would be.

The muscles which shut the jaw are supplied from the fifth pair of nerves, already alluded to as supplying the teeth. This may probably be the reason why these muscles are so liable to spasmodic action, which is not unfrequently produced by irritation of distant parts, as from punctured wounds of the thumb and great toe, when lockjaw takes place. There have been instances where these muscles have acted with such prodigious force as to crush the teeth, notwithstanding the admirable manner in which they are planted in their sockets. By the movements of the cheeks, the lips and the tongue, the food is brought in succession under the action of the teeth, which are put in motion by the action of the muscles of the jaw, till it is sufficiently triturated.

Insalivation.—During mastication, an abundant quantity of saliva flows into the mouth, and is thoroughly intermixed with the food. The saliva is furnished by three glands on each side. The largest is placed before and below the ear, in the depression between the jaw and skull; from its situation it is called parotid. The next in size lies under the angle of the jaw, and the smallest more anteriorly, under the tongue; the former, from its situation, is termed submaxillary, the latter sub-lingual. These glands are abundantly supplied with blood, and derive their nerves from the same source which imparts sensibility to the mouth and tongue. Being brought also into connexion with the nerves of the gullet and stomach, they sympathize with these parts in various conditions. Stimulating substances applied to the mouth, and particularly piquant and savoury food, excite in them a more abundant flow of the saliva. The quantity poured into the mouth at each meal amounts to six or eight ounces, or about half a pint. The ducts of the parotid open opposite the second grinder of the upper jaw, and those of the other two glands under the tongue, by the side of its frenulum or bridle.

The substances which enter into the composition of saliva are various, consisting of mucus, osmazome, and a peculiar animal matter, salivin, with six soluble, and three sparingly soluble salts; the soluble are compounds of acetic, carbonic, muriatic, sulphuric, phosphoric, and sulpho-cyanic acids, with potash in the human subject; but in other animals, as in the sheep, it is soda. The quantity of carbonate of soda in the sheep is so considerable, that their saliva effervesces on the addition of a stronger acid. The sparingly soluble salts are the phosphate and carbonate of lime and magnesia.

These are sometimes deposited on the teeth, forming what is termed the tartar, which, insinuating itself between the gum and the tooth, is not only unseemly but injurious.

Although chemical analysis thus shews that the saliva is a very compound fluid, yet it is necessary to be very chary in drawing inferences from chemical properties and composition, as to the action of animal fluids in the living body. No one, from chemical analysis, has hitherto succeeded in shewing the cause of the deadly effect of the poison of the serpent, or of the not less dreaded saliva of the mad dog; and indeed the effects of all substances upon the living system are only to be ascertained by observation and experience; little or nothing can be gained by anticipation.

From the quantity of saliva mixed with the food during mastication, it has been supposed merely to reduce the food to a soft pulpy mass, and to fit it for being swallowed, and for being more readily acted upon by the stomach. There is every reason, however, to believe, that it produces other more important than these merely mechanical effects. It acts as a stimulant, and is by no means an inert application to foul ulcers. The dog instinctively licks wounds, whereby they take on a disposition to heal. It has a great attraction for oxygen; hence metals are more readily oxidized when rubbed with it. Saliva may thus act as a stimulant to the coats of the stomach, and, by disposing affinity, induce important changes in the mass of food. At the same time, it is to be recollected, that it is a fluid immediately poured from the living blood; so that insalivation may be considered as the first step of assimilation of the food to the constitution of the animal.

The food having been assimilated in temperature, and reduced by trituration and insalivation to a pulpy mass, is gathered together by the motions of the cheeks, lips, and tongue into a convenient form to be delivered to the organs of deglutition. During swallowing, the soft palate is raised in order to shut the posterior nostrils, the tongue is carried backwards, and the larynx ascends, so that the glottis is closed. By the combined action of these different parts it is conveyed to the pharynx, which is a muscular funnel at the top of the gullet, placed behind the larynx, composed of muscular fibres arising from the base of the skull, root of the tongue, hyoid bone, and larynx. The mass of food is not only besmeared with the mucus of the mouth, but just as it enters the pharynx is plentifully lubricated with the viscid secretion furnished by the almonds of the ear, situated at the back part of the mouth, whereby deglutition is facilitated. The pharynx having received the food, propels it into the gullet, by which it is conveyed to the stomach. All these actions take place during deglutition ; they do not occur in succession, but simultaneously, so that they appear to be only one act. Beyond the limits of the pharynx distinct sensation and voluntary motion does not extend. The food is now subjected to organs which in the healthy state carry on their action without our consciousness, and over which we possess no direct control.

The *Abdomen* or belly, which is chiefly filled with the digestive apparatus, is larger then either of the other two large cavities, the head and thorax; the contents of the head not admitting of the enlargement and diminution of the cavity; while the heart and lungs, which occupy the largest portion of the chest, perform offices which are incompatible with the expansion and contraction of that cavity beyond certain limits within which the enlargement and diminution are confined, and which regularly take place in accordance with their functions, as has been already explained. The abdomen, on the other hand, admits of great variation in capacity, not only where changes in that respect take place slowly and gradually, as in dropsy, and during gestation, but likewise where they occur more suddenly, as after a full meal, or where large quantities of gases are generated.

The abdomen is bounded anteriorly and laterally by musculo-membranous walls, superiorly by the diaphragm, posteriorly by the vertebral column and muscles of the loins, and inferiorly by the pelvis or basin. It is lined throughout by a thin membrane, which, from extending over the different parts, is termed peritoneum. The peritoneum not only lines the walls of the abdomen, but covers almost all its contents, and presents an exceedingly smooth moist surface, thereby facilitating the motions of the different parts upon each other. It likewise serves to bind down and to connect the viscera; and by its numerous and extensive folds, the surface, from which a watery vapour constantly exhales, is much extended. This vapour, insinuating itself everywhere, not only lubricates the surfaces, but also serves as excellent packing, so as to support the different parts, and nowhere could a more admirable instance of packing be found than the abdomen affords.

The contents of the abdomen, excepting such as are fixed down to the back posteriorly, are subjected to constant motion, in accordance with the respiratory movements, whereby they are excited and aided in their functions, and hence partly the advantage obtained from exercise; hence also one of the many evils which arise from lacing the body with bandages or stays, where these motions are interfered with.

The digestive organs, which we have now to consider, consist of the direct and accessary; the direct being the gullet, stomach, and intestinal canal; the accessary comprising the liver, pancreas, and spleen. If we examine the alimentary tube from the gullet to the farthest extremity of the intestine, we shall find it composed of three layers or coats, as they are termed, viz. the mucous, the submucous, and the muscular. In the abdomen, the peritoneum furnishes a fourth, the serous coat, which in some parts is only a partial covering. The mucous coat lines the whole internal surface, and is that with which matters traversing the tube come immediately in contact. Throughout its whole extent it is studded with numerous glands, furnishing a viscid fluid or mucus, which serves as a protection to the very sensitive surface, and at the same time facilitates the passage of substances along it, by rendering it smooth and slippery. These glands are like little bottles with short necks. They are furnished with a muscular power, by which they expel their secretions, and also with another set of muscular fibres, which form a fillet round their mouth, by which their contents are retained until their mouths are excited, so as to call forth their action, and cause them to evacuate themselves. They vary in size: In some places they are small, and collected in clusters; while in others they are larger, and more scattered. Besides the mucus which lubricates the surface, there is constantly exhaled a thin watery fluid, which is derived immediately from the vessels terminating upon it, without the intervention of glands. This fluid intermixes with the aliment as it passes along, dilutes it, and effects important changes in it, as in the stomach, where it is called the gastric juice. It is not always produced in equal quantities, but the quantity varies according to different causes, as the presence of the aliment, or stimulating substances, such as medicinal agents of various kinds. Gases are also secreted from it, sometimes in great quantity, producing flatulency. These gases vary, being of different kinds, and in different states and situations.

The mucous lining is by far the most extensive of the coats of the intestine, being formed into numerous folds, so as to present an extensive surface both for secretion and absorption. In the stomach the folds are irregular in their direction, though generally longitudinal, while in the intestine they are transverse, forming a series of segments of circles, lying one upon another like tiles.

Beneath the mucous coat is a layer of condensed cellular membrane, that universal animal tissue which is diffused over the whole body, affording coverings for the different organs and parts of organs, and insinuating itself every where. It imparts strength to the tube, and the mucous follicles or glands are inserted upon it.

The muscular layer consists of two sets of fibres, the external or longitudinal running lengthways, the internal transversely. The longitudinal are strongest and most conspicuous in the gullet and the extremity of the gut. They tend to diminish the length of the tube when in action, and are more powerful in the parts mentioned, being there partly under the command of the will, and employed in propelling more solid matters than in the rest of the canal. The transverse fibres do not form rings, but segments of rings, whereby the centres of contraction are increased, and the resulting effect greater. They diminish the transverse diameter of the tube. Thus, the combined action of both sets will be to contract the tube in all its diameters. The following is the mode of their action:—Supposing a portion of alimentary matter is sent into the first portion of the intestine, its presence excites the action of the muscular coat, whereby the contents are embraced and pushed forwards into the next part beyond, which at the time is empty, and ready to receive; but the contraction of the first does not immediately relax on having expelled the matter: it continues for some time, in order to prevent the return of the aliment on the action of the second, so that it is forced into a third portion, which in its turn becoming excited, forces it onwards. In this way, a slow undulating motion is produced, whereby the contents of the intestinal tube are gradually and slowly carried along, yet not with the same degree of motion in every part, being retarded in some parts, in order to become subjected to changes, while it is accelerated in others.

The *Gullet* is a cylindrical tube by which the aliment is conveyed from the pharynx down the neck and through the back part of the chest into the abdomen, where its coats are expanded to form the stomach.

The *Stomach* is a large pouch or bag situated at the upper part of the abdomen, lying under the left short ribs, extending across what is called the pit of the stomach, at the end of the breast bone towards the right side. In shape it resembles the bag of the bag-pipe. In fact, it is not unlikely that the first kind of bag for that instrument was the stomach of some animal. The left portion of the stomach, in which the gullet terminates, is the largest. From its proximity to the heart it is termed the cardiac extremity. As it approaches the right side, it becomes contracted, and terminates in the intestine, where there is placed a valvular apparatus, by which the entrance into the intestine is guarded, and which is therefore named the pyloric valve. Hence too the name pyloric extremity of the stomach. The cardiac portion serves principally as a receptacle, while in the pyloric portion the peculiar changes produced upon the food are chiefly effected. The stomach is composed of the number of coats mentioned, which are abundantly supplied with blood and nerves, the latter being received more directly from the brain than the portions of the alimentary canal beyond it.

The *Duodenum*, so termed from being about twelve inches in length, is the first portion of intestine beyond the stomach. By its turns it very nearly forms three sides of a square; it is more capacious than the rest of the smaller intestine, is fixed in its position, and has the ducts from the liver and pancreas opening into it.

The next portion of intestine is of the greatest length, is somewhat more contracted, and variously coiled, especially towards the left side and middle of the abdomen, and terminates on the inside of the right haunch-bone, in the great gut or colon. At its termination there is a valve, whereby any substance is prevented from returning into it after it has entered the colon.

The *Colon*, or great gut, is, as its name indicates, capacious. It is furnished with three bands of ligamento-muscular tissue, which run along it longitudinally; they contract the length of the gut so as to form it into cells. At its commencement the colon forms a shut sac, which is abundantly supplied with mucous glands; it then proceeds upwards towards the liver, crosses under the stomach to the left side, down which it descends, where it is much twisted, and finally enters the basin, where it is called rectum, from the bowel being here straighter than in any other part.

The *Rectum* is furnished with more powerful longitudinal muscular fibres than any other portion of the intestine. At its extremity it is guarded by a muscle which closes it like the mouth of a purse. These muscles, besides being supplied with nerves in common with the rest of the intestine, receive filaments from the extremity of the spinal cord, whereby a certain degree of voluntary power is possessed over this part, so as to retain or expel the contents under the command of the will.

A general view may now be taken of the accessary digestive organs, namely, the liver, pancreas, and spleen.

The *Liver* is the largest gland in the body, weighing about four pounds. It occupies the right superior region of the abdomen, in contact with the diaphragm, to which it adheres. It is divided into lobes by fissures, which are more or less deep in different animals, being more completely divided in those which have a flexible spine, so as to admit of ready adaptation to various postures of the body. Its structure is composed of an infinite number of minute granules, connected with each other by cellular tissue. The circulation through the liver, as has been already mentioned in the chapter on circulation, is peculiar, the artery being comparatively small, as conveying arterial blood merely for its nourishment, while the venous blood from the stomach, intestinal canal, spleen, pancreas, and folds of the peritoneum, is brought to the liver by the vein termed porta, by which it is minutely distributed through this gland, and from it the bile is elaborated. The very languid circulation of blood in the porta admits of the slow and gradual formation of bile, a fluid composed of substances very distinct from the constituents of the blood. Being abundant in carbon and hydrogen, the venous blood, containing a great proportional quantity of these elements, becomes better fitted for furnishing materials for the biliary secretion. The bile transudes through minute pores, and is immediately drunk up by small tubes, which, by reiterated unions, form one bile duct, which proceeds towards the first portion of the intestine. In its course there branches off from it a duct, which terminates in a sac, the gall-bladder, where the bile accumulates till required, where bitterness is imparted to it, and where also the thinner parts are reabsorbed, so that the remainder is thickened. In some animals, as the horse, there is no gall-bladder, in which case the bile is immediately conveyed into the intestine.

The bile is a greenish-yellow fluid, with a peculiar heavy odour, and a taste at first sweetish, followed by an exceedingly nauseous bitter. It is a very compound fluid, and chemists disagree as to its constituents. It is extremely difficult to obtain uniform and satisfactory results from the chemical examination of organised substances, and very difficult to distinguish between their constituents and such as are the products of the processes to which they may have been subjected. Fluids, such as the bile, when removed from the living body, are immediately brought under the full influence of the general laws affecting dead matter: spontaneous changes commence, a separation of the different parts takes place, and the temperature is no longer the same as in the living body. The bile may be stated to be a fluid containing water, with salts in solution, some common animal principles, and others peculiar to itself. The salts are compounds of the following acids:—colic acid, peculiar to the bile; margaric, oleic, acetic, carbonic, sulphuric, muriatic, and phosphoric, combined with soda; the last is also united with a little lime. To the carbonate of soda the bile owes its alkaline property, and hence it is sometimes used for the purpose of cleansing. The common animal principles are mucus derived from the lining membrane of the gall ducts, a modification of albumen, and osmazome. The peculiar principles are a yellow colouring matter, resin, and a substance, the taste of which is first sweet and then bitter, hence named picromel; but, when pure, it is sweet without bitterness, the latter quality being owing to the bile which it holds in solution, and for which it serves as a solvent. Besides, in the human bile another peculiar substance has been detected. From its forming the basis of, and giving consistence to, gall-stones, it is called cholesterine; in external appearance it very much resembles spermaceti.

The *Pancreas*, or sweetbread, is an elongated gland, about five or six ounces in weight, lying in the curvatures of the duodenum, and presenting a structure very much resembling the salivary glands, whence it was inferred that it furnished a secretion similar to the saliva. Later examinations have shewn that the pancreatic fluid differs from that secretion in containing a considerable quantity of albumen, a curdy substance, and in the absence of sulpho-cyanic acid; the fluid secreted by the pancreas is collected by the branches of its duct, which terminates generally, in common with the bile duct, in the duodenum.

The *Spleen* is a dark purple or livid-coloured body, weighing about eight ounces, situated in the left side, and attached to the stomach and some neighbouring parts. It is of a loose, spongy, and exceedingly soft texture, very abundantly supplied with blood-vessels, but has no ducts; nor does it appear to elaborate any peculiar secretion from the blood. The purpose it serves will hereafter be examined.

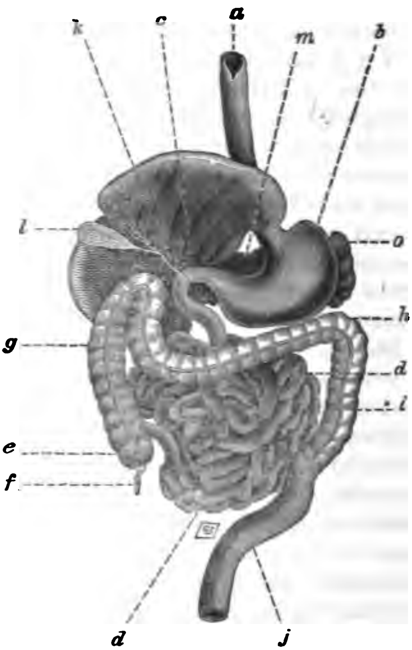

FIG. 13.

The above engraving will give an idea of the general form and relative position of the different organs engaged in digestion:—*a* is the gullet; *b*, the stomach; *c*, the duodenum; *d*, the convolutions of the small intestine; *e*, the cœcum; *f*, the appendix of the cœcum; *g*, the ascending colon; *h*, the transverse arch of the colon; *i*, the descending colon; *j*, the rectum; *k*, the liver; *l*, the gall-bladder; *m*, the pancreas, the greater part of which is covered by the stomach; *o*, the spleen. In the engraving the liver is elevated, and the transverse arch of the colon drawn down, in order to shew parts which they cover in their natural position.

When we consider the infinite variety of food on which animals subsist, we will be prepared to expect great diversities in the construction of the digestive organs. Yet it will be found that they are all formed upon the same general plan, from the highest to the lowest, though variously modified, so as to adapt them to the condition of each. It may be useful to advert to some of these modifications before entering upon the consideration of the action of the digestive apparatus, and the results of that action in the human subject.

In those animals of the class mammalia which subsist upon flesh, such as the lion, the tiger, and the cat, the stomach is simple in its structure, the intestinal canal comparatively short, and the motions quick. The vascular distribution is also such as to admit of ready entrance of the new matter into the general system. On the other hand, in those which live upon crude vegetable food, such as grass, the digestive organs are complicated.

In ruminating animals, as in the ox, sheep, deer, &c. there are four stomachs. The animal transmits the food into the first stomach without subjecting it to mastication in the first instance. This capacious cavity, known by the name of paunch, is of a somewhat globular form, lined internally with a dense insensible scarf skin, studded with numerous papillæ, and usually divided into distinct pouches by strong muscular bands. It exerts a rotatory motion, whereby, when indigestible substances, such as hair, are introduced, they are formed into round balls, as often occurs in oxen, from their licking their hides. It always contains a portion of the previous meals, for when the animal is even starved to death, a portion of food is still found in the paunch. This may be considered as a kind of cooking vessel; the food, on being introduced into it, is subjected to the internal heat of the animal, is brought in contact with that which for sometime has been under action, and kept in motion by the muscular power of this stomach.

The second stomach is much smaller, and appears as an appendage to the first. It too is lined with insensible cuticle, and divided into numerous cells, generally of a hexagonal shape. It is termed the honeycomb, or king's hood. It appears chiefly to serve as a reservoir for fluids. In the camel and dromedary there are several pouches connected with this cavity, each capable of containing a considerable quantity of water. Their orifices are commanded by a sphincter muscle, whereby the water is retained without being contaminated with the adjacent food. These animals drink seldom, but take a large quantity at once, which is stored up for many days without undergoing change, remaining perfectly sweet and clean. We thus see how admirably they are constructed for traversing the arid deserts in which they are placed. The life of the traveller is occasionally preserved by his sacrificing that of his camel in order to procure the water contained in the cells of the honeycomb.

The ruminant possesses a voluntary power over these two stomachs. When he chews the cud, a portion of food is detached from the general mass, probably a part of that which has been for the longest time lodged. As it passes the second stomach it receives a quantity of moisture, and is returned to the mouth, where it is subjected to trituration and insalivation.

On being swallowed for the second time, by a curious power possessed over the gullet, it is transferred to the third cavity, which is the smallest of the four. Like the two former it is lined with cuticle, which is folded into broad plaits, from which circumstance it has obtained the name of many-plies. It has not been clearly ascertained what action the many-plies has upon the food; but that a certain chemical effect is produced, appears from the fact that here hydrogen gas is disengaged in considerable quantity.

The fourth stomach is to be considered as the proper digestive organ; it is named the rennet. Internally the rennet is covered by a soft delicate mucous membrane, formed into longitudinal folds, and gastric juice is secreted in this compartment. In the suckling, the milk does not enter any of the three first, but, by a peculiar management of the gullet, it is immediately transferred into the fourth stomach, where it is curdled by the gastric juice, this being the first change to which it is subjected. This power of coagulating milk possessed by the gastric juice is one of its most striking and remarkable properties. The rennet, even after being salted and dried, retains the power of imparting to water, on being infused in it, this quality; and accordingly that of the calf is prepared and preserved for this purpose in dairies.

The three first stomachs in ruminating animals may be held as merely subsidiary to the first, where the crude vegetable matter undergoes a process of preparation which may be compared to the effects of cooking, so as to render it more susceptible to the action of the proper stomach. Where, however, such influence is unnecessary, as in the case of milk, the food is not introduced into them, but directly conveyed into the fourth.

Notwithstanding the length of time, and the extent and complexity of apparatus to which crude vegetable food is exposed in these animals, it is calculated to yield but a sparing quantity of nourishment. Accordingly, the intestinal canal is long and capacious, so as to afford both time and surface, that the whole of the nutritious portion may be taken up, and that every particle capable of furnishing nutriment may be abstracted.

In monogastrics—that is, animals with a single stomach which subsist on vegetable food—various modifications of the digestive organs, so as to adapt them to their office, may be observed. The stomach is divided into two portions, especially during the process of digestion, the left extremity serving as a capacious reservoir where the food is lodged and prepared previous to its being brought under the action of the right portion, in which the proper conversion into chyme is effected. In the horse, the left portion is lined with dense insensible cuticle, as in the three first stomachs of ruminants. The length and capaciousness of the intestinal canal, especially of the colon and its appendage the cœcum, in monogastric herbivorous animals, compensate for the less elaborate construction of the stomach. In the horse the colon is very large: so it is in the hare and the rabbit. The food, therefore, after having been subjected to the action of the stomach, and the chyme there produced being changed into chyle, which is absorbed in the smaller intestines, the residue is transferred into the larger intestine, where it is lodged for some time, and there intermixed with new juices, having been previously softened and otherwise altered in its passage along the superior organs. The last efforts are now made to abstract nourishment from it, after which the effete residuum is ejected.

The circulation of the blood is in perfect accordance with the various conditions of the organs of digestion in different animals. Where the quantity of chyle is abundant and rapidly produced, as in the carnivorous animals, the circulation is rapid; while in the herbivorous animals, where the production of chyle is more gradual, the circulation is correspondently slow. In the pig, the mesenteric arteries, which supply the intestinal canal, have their primary divisions formed into bundles of very intricate network, from which the vessels immediately distributed upon the bowel are given off. The veins also present the same distribution, and are curiously interwoven with those of the arteries. This kind of circulation must be necessarily sluggish, but gentle and uniform, affording ample time for complete absorption of the nutritious chyle.

In birds, numerous modifications in the digestive organs obtain, adapted, as in the mammalia, to the nature of their food. My friend Mr Macgillivray has lately, in his excellent work on British birds, with great success adopted the digestive organs as the basis of his arrangement.

In birds the gullet is capacious. At its lower extremity it is dilated into what is termed the proventriculus, the internal surface of which is studded with numerous mucous glandules, frequently symmetrically arranged. In the proventriculus, the proper gastric juice is also secreted, for in many birds the stomach is lined with a hard and dry membrane altogether unfit for the office of secretion. The stomach in carnivorous birds, as in falcons, is simple and membranous. The intestinal canal is not so definitely divided into distinct portions, that is, into smaller and larger, as it is found to be in mammalia. Towards its extremity there are two blind guts or cœca, and the extremity or rectum terminates in what is called the cloaca, being the common termination of the intestine, urinary, and genital organs. In granivorous birds, the gullet is dilated into a remarkable pouch, named crop, which serves as a reservoir for the food, where it also undergoes slight preparatory changes, analogous to those in the first stomachs of ruminants, and in the left portion of monogastric herbivorous quadrupeds. In some, instead of a distinct crop, the capaciousness of the gullet serves the same purpose. In the proventriculus, the necessary fluids are furnished for the process of digestion. The food is then transferred to the proper stomach, which in those that live on flesh and on fish is simply membranous, in accordance with the nature of the food, which is easily and rapidly changed into chyme. But in granivorous and insectivorous birds, the stomach is more complicated in its structure; its internal lining becomes hard, dry, and insensible, and almost of horny consistence; the muscular coat is largely developed, and formed into distinct and powerful muscles, by the contraction of which the contents of the stomach or gizzard (as it is named when of this construction) are crushed and reduced to a minute state of mechanical division. The action of the gizzard is aided in reducing the food by quartz and other hard angular stones, which the bird instinctively swallows. The length and capacity of the intestine varies much. In gallinaceous birds, in particular, as the domestic fowl, the cœca are very capacious, affording the best opportunity for the abstraction of nourishment like the largely developed cœcum and colon of herbivorous quadrupeds; while in most carnivorous birds the cœca are merely rudimentary.

The stomach in man is intermediate between that of the carnivorous and monogastric herbivorous quadrupeds, being more developed in the former, and less so in the latter. The intestinal canal is longer, and more capacious than in animals which live entirely on flesh. But though the colon is large, it is not of the same proportional size as in those which are confined to vegetable food.

Food is derived either from the animal or vegetable kingdom, and has consequently been previously organized. By digestion, the aliment is reduced to a new condition, and by admixture with the fluids with which it meets, becomes assimilated to the constitution of the animal.

The Proximate Animal Principles, as food, are fibrin, albumen, gelatin, osmazome, and fat: they are compounds of four elementary principles, carbon, oxygen, hydrogen, and nitrogen, with the exception of fat, which is deficient in nitrogen.

Fibrin is a white translucent elastic substance, insoluble in water, but softened by immersion in it. It is the chief constituent of the flesh of mammalia and birds, and of the coagulum of the blood. The flesh of adult animals contains a greater proportional quantity of it, and is also firmer and more easily digested than that of the young. Thus beef and mutton are both more nutritious and more easily digested than veal and lamb; the flesh of animals that are at liberty, and able to take healthy exercise, than that of those which are kept in confinement.

Gelatin, when pure, is colourless, semi-transparent, and tasteless. It is obtained chiefly from the skins of animals, cartilages, the animal part of bones, and the sounds of fishes. It is also found in considerable quantity in the flesh of young animals. Gelatin is softened by cold water, and dissolved in hot. Its solution concretes, on cooling, into a tremulous mass called jelly.

Albumen is the most generally diffused of the proximate animal principles. It is found in two conditions; in solution in the blood and various secretions, and in the solid form in flesh, tendons, ligaments, cartilage, horns, hoofs, and membranous parts. The white of an egg consists of albumen nearly pure. It is soluble in cold water, and coagulated by heat. Albumen, along with a little oil in the yolk, is the nutritive substance in eggs; as also of fish, combined with gelatin, and in some with oil.

Osmazome is so named from having the smell of broth, to which it gives the characteristic odour and taste. It is of a brownish colour, soluble both in cold and hot water.

Fat is a well-known substance, similar to the fixed oils of vegetables. It is composed of two principles, stearine, a white concrete substance resembling wax, and elaïne, a limpid fluid. The relative proportion of these two determines the consistency of fat. Although subservient to several secondary purposes, fat can scarcely be considered as an essential animal constituent. It appears rather to be a superaddition to the system, when the nourishment exceeds the current expenditure, and serves as a magazine from which the system may draw, under particular circumstances.

Proximate Vegetable Principles.—The following are the chief nutritive vegetable principles:—Gluten, vegetable albumen, starch, sugar, vegetable jelly, gum, and fixed oils. With the exception of the two first, which contain nitrogen, they are all ternary compounds, consisting of carbon, oxygen, and hydrogen.

Gluten is a grey, viscid, elastic, and very adhesive substance, very sparingly soluble in water. It is obtained from the cultivated grains, especially from wheat, the superiority of which for food has been attributed to the quantity of gluten it contains. It is also found in the pulse tribe, and in almonds, chesnuts, &c. The cow-tree, which flourishes in the mountains of Quito in South America, furnishes an abundant quantity of sap, having the exact appearance and taste of milk, and used as a substitute for that fluid by the natives, contains a modification of gluten. When wheaten flour is put into a coarse canvas bag, then washed and kneaded in water, the mucilaginous part is dissolved and removed, the starch is suspended in the water, and the grey tenacious mass which remains consists of gluten and vegetable albumen. By acting upon this mass with boiling alcohol, the gluten is dissolved, and the albumen remains. From the close resemblance which gluten has to animal principles, it has been held to possess superior nutritive properties. But the influence it exerts in fermentation, in which it is an important agent, and its tenacity, also contribute to its importance. During fermentation in making bread, carbonic acid is disengaged, but prevented from escaping by the adhesive quality of the gluten whereby it is rendered light and spongy. The flour of barley and oats, having less gluten, do not form *sponge*, as it is called by bakers.

Vegetable albumen remains after gluten has been removed by alcohol from the glutinous residue of wheat flour. On drying, it becomes brittle and pulverulent. It is sparingly soluble in cold water, and, like animal albumen, is coagulated by heat. It is found in mushrooms, and in different other species of fungi. Almonds afford about thirty per cent of a substance resembling coagulated albumen. The juice of the fruit of the ochra, according to Dr. Clarke, contains a liquid albumen in such quantities that it is used in Dominica as a substitute for the white of eggs in clarifying the juice of the sugar cane. Vegetable albumen differs little in its essential properties from gluten.

Starch, or fecula, is a white tasteless and inodorous substance, insoluble in cold water, but readily dissolved in water at a temperature between 160° and 180°. If the temperature be raised above 180°, it coagulates into a thick tenacious transparent jelly. When heated till it becomes brown, it is changed into a substance resembling gum, soluble in cold water, giving a mucilaginous solution. It exists in seeds, particularly of gramineous plants, and in tuberous roots. It is procured by pounding, grating, and washing with cold water. In this way it is obtained from wheat, or from potatoes. Sago is extracted from the pithy substance of palms of the genus Sagus. Tapioca and cassava are got from the South American plant Jatropha Manihot, the juice of which is so virulent that the Indians employ it for poisoning their arrows. The poisonous principle is, however, removed by washing, or it may be dissipated by heat. The Maranta arundinacea furnishes Indian arrow root; and different species of the beautiful genus Orchis, particularly the Orchis mascula, afford salop. Most lichens contain a species of starch. Thus the Iceland moss is employed by the natives of that country as an article of food, and is, as well as other lichens, occasionally prescribed for the sick. Starch is yielded by the roots of a great variety of other plants. Frequently it is associated with bitter, resinous, acrid, and poisonous principles. For example, in gentian root it is combined with a pure bitter; in jalap, with a resinous purgative; in ipecacuan, with an emetic principle; and in Jatropha Manihot, with a penetrating subtle poison. In this way, the mild nutritious starch is protected from the attack of grubs, &c. to which it would otherwise have been much exposed.

When gluten is present, as in the seeds of plants, starch is converted into sugar, on being exposed to a proper temperature, air, and moisture. When gluten is absent, the change takes place very slowly. This conversion of starch into sugar occurs during germination of seeds. In the process of malting, the grain is steeped in water, then made up into a heap. When germination commences oxygen is absorbed, and carbonic acid evolved, and the temperature is elevated. At the proper point the fermentation is checked by exposure to heat in a kiln, when the malt is perfected, the starch being now changed into sugar. The stage of germination is critical in the growth of cultivated plants, especially of wheat; for the sugar invites the attack of grubs and insects, whereby extensive depredations are frequently committed. Starch is also converted into sugar by the agency of some acids, such as sulphuric, nitric, muriatic, and oxalic; and the actual sugar thus obtained exceeds, by about one-tenth, the original weight of the starch. Dr. Prout considers wheat starch as the most perfect, and arrow-root as the lowest of the varieties, the former by an easy transition passing into sugar.

Sugar is well known for its sweet taste. It is soluble in its own weight of cold water, and in a very small quantity of hot water. From recent researches it appears that there are several varieties of saccharine matter. In its most perfect form it crystallizes into white semi-transparent six-sided prisms. Another variety is uncrystallizable, charged with a considerable quantity of colouring matter, familiarly known under the name of treacle. Sugar may be obtained from a number of vegetables, and is contained in all those which have a sweet t ste: it is commonly procured frŏm the sugar-cane. In North America an inferior kind of sugar is obtained from the juice of a species of maple growing wild in the woods. A tree of average size will yield 50 quarts in 24 hours, containing 5 per cent of sugar. The sap continues to flow for five or six weeks. Sugar exists in all sweet fruits: grapes, in good seasons, yield from the expressed juice nearly from 30 to 40 per cent of solid matter, the greater part of which is sugar. The roots of many plants afford it, such as beet-root, parsnips, and carrots. In France, the beet is extensively cultivated for sugar: 100 lbs. of the root furnish from 4 to 5 lbs. of purified white sugar, besides a quantity of syrup, at an average expense in that country of between 3d. and 4d. a pound.

Mannite, or manna sugar, is a species of sugar most abundant in manna, a sweet juice which exudes from several species of ash: four-fifths of the best manna consists of this variety of sugar. It is also contained in the sap of some of the pine tribe, and onions, celery, asparagus, and other sweet plants.

Honey, secreted by flowers, and collected by bees, contains two kinds of sugar,—the one crystallizable, the other not so, combined with wax, gum, colouring matter, and principles which impart taste and smell, according to the nature of the plants from which it is gathered. In some instances it proves poisonous, from being collected from plants possessed of deleterious qualities.

Milk furnishes a species of sugar: in Switzerland it is an article of commerce. It is slowly soluble in three parts of hot and six of cold water. In certain diseased states of the human body, as in diabetes mellites, the urine yields by evaporation a considerable quantity of saccharine matter, similar in properties to common sugar. It has been already stated that starch is converted into sugar by several of the acids; and by the agency of sulphuric acid, linen rags, saw-dust, and other substances, have been changed into more than their own weight of crystallizable sugar.

Sugar is pre-eminently nutritious. Although it soon cloys the appetite, it is readily digested by the young, and again it is relished in decrepit old age. During the sugar harvest, the West Indian negro has more continued and laborious exertion than at any other period of the year; yet notwithstanding he generally becomes fat and in good condition, which is attributed to the quantity of cane juice which he devours at pleasure. Dr Copland gives an interesting case, illustrative of the nutritive properties of sugar. He says, " A case which fully exemplifies the nutritious quality of sugar, lately came under our observation in a lady about the middle age, who consulted us respecting great and increasing corpulency. Her countenance was full, clear, and florid; her pulse strong; her health excellent; her strength very considerable. She partook of animal food only once in a day, and then in a very small quantity. She never took suppers, and was very moderate in the use of fluids. She had always taken considerable exercise on foot; and even up to the period at which we saw her, she resorted to it as much as the great bulk of her body could permit. The secret, however, of her obesity was disclosed, when she mentioned her insatiable desire for refined sugar, which she almost hourly made use of, frequently to the extent of one pound weight daily. She considered it her chief article of diet. She reckoned the average quantity she used at about three-fourths of a pound in the day. Tea or coffee was taken by her sweetened in the usual way. She ate the sugar in the solid state, and unaccompanied with any other article of diet: the finest sort only was relished. Her digestive functions were in a perfect condition; neither cardialgia, acidity, nor flatulence, were complained of. Her teeth were sound. She found her corpulence supervene to a spare habit of body, some time after the practice of eating sugar was acquired. She thought that the obesity increased with the increased quantity of sugar which she consumed. The habit had become so confirmed at the time when we saw her, that she conceived it to be quite impossible to relinquish it."

Vegetable jelly is obtained from various acid fruits, as currants, gooseberries, raspberries, cherries, &c. by boiling the recently expressed juice so as to dissipate the water. It is sparingly soluble in cold, but abundantly dissolved in hot water. As the solution cools, it again assumes a gelatinous form. By protracted boiling it loses the property of coagulating. It is supposed that vegetable jelly is merely gum in combination with an acid.

Gum is a brittle, transparent, colourless, inodorous, and tasteless substance. In its purest form it is known under the name of gum arabic. It is soluble both in cold and hot water; its solution is called mucilage. Gum appears to be the first transition that the sap of plants undergoes. It is found in greater or less quantity in all young plants, and exists in every part of vegetables: it is so abundant in some that it exudes spontaneously, while from others it is procured by incisions made in the bark. As obtained from different plants, it varies in its properties: a variety exudes from the cherry-tree, whence named cerasin, which differs from gum arabic in many respects. When cold water is added to it, it swells considerably, and is softened but not dissolved. It is sparingly soluble in hot water. Gum tragacanth is a variety of this. Between the very soluble gum arabic and the nearly insoluble tragacanth there are many shades of varieties procured from different plants, as from the decoction of linseed, marshmallow, onions, and other bulbous roots, fuci, lichens, and many others. By the action of sulphuric acid on vegetable fibre, gum is formed artificially. Starch, when heated till it becomes brown, is converted into a gummy matter used by calico-printers under the name of British gum. Again, by the action of alkalies, sugar is changed into a kind of gum. The Arabs who collect the gum arabic in the forests of Senegal, subsist upon it during the gum harvest, and the subsequent journey across the desert. Hasselquist mentions in his voyages, that a caravan of Abyssinians, consisting of 1000 persons, must have been starved to death, had it not been from their having a parcel of gum, on which they subsisted for two months.

Fixed or fat oils, of which there is a great variety, are viscid, nearly insipid, with little smell, and when pure, semi-transparent. They are all lighter than water, and insoluble in it. They consist of the same constituents as animal fat, viz. of elaïne and stearine. At the ordinary temperature of the atmosphere, the greater number are liquid, but solidify before they are reduced to the freezing point of water. A few of them, as palm oil, the oil of nutmeg and of cocoa nut, are solid at ordinary temperatures, when they are called vegetable butters. Fixed oil is generally obtained from the seeds of plants by compression, or occasionally by boiling. Olive oil is extracted from the fleshy part of the fruit of the olive. The roots and bark of some vegetables afford fixed oil. As an article of diet, fixed vegetable oil has been known from the earliest periods of history, and is in extensive use at the present day, being generally preferred in warm countries to animal fats, which are more commonly employed by the inhabitants of colder climates.

The five animal principles now mentioned, viz. fibrin, gelatin, albumen, osmazome, and fat, with the seven vegetable principles, gluten, vegetable albumen, starch, sugar, vegetable jelly, gum, and fixed oil, comprise nutritive matter in all its shades and diversities, obtained from organized nature. None of these principles are alone well calculated for the proper sustenance of the more perfect animals. For although life may be sustained for a considerable time by the exclusive use of one, such instances are to be considered as exceptions to the general rule. It has been found, by experiments both on man and the lower animals, that health declines when the food is restricted to one article, such as sugar. Habit exerts a powerful influence in this respect. Climate likewise produces a considerable effect. When we extend our inquiries over the globe, we shall find that the majority of the human race subsist chiefly on vegetable food, and that principally derived from gramineous seeds. Thus the millions of China and Hindostan live almost exclusively on rice; wheat, barley, rye, and oats, furnish subsistence to another large class of mankind; maize supplies another; while others derive their aliment from roots and herbs. On the other hand, the shepherds in the province of Caraccas, in South America, live entirely on mutton; some tribes of Tartars on horse flesh; the natives of Kamtschatka scarcely on anything but fish; and the Esquimaux devour enormous quantities of raw blubber.

The inhabitants of warm climates generally prefer a vegetable diet, not merely because nature furnishes a great abundance and variety of this kind of food, but from choice. Vegetables are productive of less heat and irritation, and therefore much better adapted for aliment in hot climates. Confinement to vegetable diet and abstemiousness constitute, in such countries, an easy virtue. "Religious sects," says Richerand, "by which abstinence from animal food was considered a meritorious act, were all instituted in warm climates. The school of Pythagoras flourished in Greece; and the anchorets who in the beginning of the Christian religion peopled the solitudes of Thebais, could not have endured such long fastings, or supported themselves on dates and water, in a more severe climate. Thus, the most austere were induced to add to vegetables, which formed the base of their food, eggs, butter, fish, and even water-fowl. In books of casuistry it may be seen on what ridiculous grounds there was granted a dispensation in favour of plovers, of water-hens, wild-ducks, snipes, and scoters,—birds whose brown flesh, more animalized and more heating, ought to have been proscribed from the kitchens of monasteries much more strictly than that of common poultry." The inhabitants of cold regions prefer animal food, not merely from vegetables being scanty, ill adapted for nourishment, or altogether wanting, but because they instinctively make choice of animal diet, in order to enable them to brave the rigours of the climate they inhabit.

Food is required not only to build up the growing frame in childhood, or sustain the constant renewal of parts in maturity, but also to compensate for the constant expenditure which occurs from the functions which are carried on, without intermission, in the living body. It has been already observed, when treating of the regulation of animal heat, that in hot climates there is a determination of blood to the surface, and a large portion of the thinner part discharged by sensible and insensible perspiration, whereby the heat of the body is reduced. In order to make up for this loss in the watery part of the blood, fluids are craved, and fruits and vegetable diet had recourse to. It has also been stated that animal temperature is sustained by chemical changes which take place in the constitution of the blood, especially in the production of carbonic acid; that the quantity of carbonic acid generated has a relation to the temperature of the animal; that a greater quantity is given off in winter than summer; and that vegetable diet produces less than animal food. Blood derived from animal food being better calculated to sustain the expenditure of heat, and invigorate the system, is not only taken with impunity in cold climates, but with the greatest advantage, in large quantities, and sometimes even in an advanced state of decomposition, which in a hot country would inevitably produce fevers of the most malignant character.

It is not by the quantity or quality of the food taken into the stomach, but by what is digested, that the body is nourished. The digestibility of the aliment is therefore of much importance. For, if it be not converted into proper chyme and chyle, a crude mass remains, which is often productive of serious consequences. The fault, in such instances, may either be in the food or the state of the stomach.

Highly concentrated aliment is not of easy digestion. Thus the portable soup prepared for the voyagers of the polar expeditions was not fit for nourishment till adequately diluted, notwithstanding the energies of the stomach were fully called into action by the rigour of the climate, and the laborious employments the adventurers were engaged in. Is it to be wondered at that digestion fails where the indolent inactive citizen loads his stomach with rich gravies and concentrated soups, however the flagging appetite may be spurred on by piquant sauces, and all the arts of cookery.

It has been stated that single chemical principles are not adequate for proper nourishment; that when animals are thus fed they become incapable of digesting a sufficient quantity to support the wants of the system, and that consequently health and strength rapidly decline. A mixture or variety of food, whether vegetable or animal, becomes therefore requisite. In the same way occasional variation of diet is beneficial. Both mixture and change of food require, however, to be had recourse to with discretion. At a feast where all sorts of aliment, in every variety of preparation which the ingenuity, science, and experience of the cook can supply, are introduced into the stomach, it is impossible that such a complicated mixture can be converted into sweet and healthy chyme, however energetic the action of the digestive apparatus may be. Much less can the proper conversion be effected where the tone of the stomach has been impaired and its vigour shaken. So also the sudden transition from one kind of diet to another cannot be otherwise than prejudicial.

The consistency of aliments has a very considerable influence on their digestibility. Dry and hard food, such as hung and salted meats, hard boiled eggs, &c. are digested with difficulty. Soups and other liquid aliments are also not easily acted on. A medium state of density and coherence is favourable to the digestion of food. Nor is it difficult to understand the reason of this. Dense and hard matter resists the solvent power of the gastric juice, and requires a long time before it is reduced to a proper state of softness and liquidity, while soups elude the grasp of the muscular action of the stomach, and are not digested till the fluid part is drunk up, when the more consistent residue is brought under the influence of the digestive agents.

The texture and cohesion, and consequently the digestibility of food, depends much upon the state in which it is taken. The nature of the animal, its age, sex, and condition, the manner of its death, and the length of time the flesh has been kept, have an important influence; and the different processes of cookery produce great changes in these respects, by the various forms of boiling, roasting, broiling, frying, and baking.

Quantity also operates: unless a certain bulk be introduced, the action of the stomach is not fully brought into play. To a considerable extent this depends upon habit. A curious instance of this was afforded by a highland regiment. The men in their native hills had been accustomed to fill their stomachs with a large quantity of food, possessing comparatively slight nutritive qualities, but which called forth the full exercise of their stomachs, whereby they were adequately nourished. Being transferred to one of the midland counties of England, they had distributed to them beef and wheaten bread, instead of oatmeal porridge and cabbage broth, when they declared themselves to be starved under the latter diet, though it was furnished to them in quantities quite sufficient to satisfy the appetites of Englishmen.

The most judicious selection and careful preparation of food are unavailing, if the stomach be not prepared to perform its duty. Age, state of health, and custom, have a powerful influence on the action of the stomach. Milk is furnished by the hand of nature expressly for the diet of the young of mammalia. Derived from such a source, we can have no hesitation in acknowledging that it must be not only the best, but also the only nourishment they can properly digest. In adult age, however, milk is by no means of easy digestion, unless custom has long habituated the stomach to it. Many substances are digested with facility in robust health, which the digestive powers of the valetudinarian are totally unable to cope with; while in some diseased conditions, large quantities of food are rapidly acted on, and substances chymified which in ordinary health altogether resist the agency of the stomach. No organs of the body so readily and so completely adapt themselves to varying circumstances as the digestive apparatus. Notwithstanding this accommodating facility, habit exerts a powerful effect. To the Greenlander train oil affords a delicious repast; while he neither relishes, nor readily digests biscuit. Again, the Hindoo easily disposes of his meal of rice, while his stomach would turn with loathing from food highly prized by the Esquimaux or the Russian boor.

Drink.—Food comprises all those substances which are altered, reduced, and assimilated to the constitution of the animal by the digestive organs, for the formation of the more consistent materials of the system. Water, either in combination or in mixture, enters into the formation of every tissue of the body. As a constituent, it may be considered of the nature of food. So far as it is in mere mixture, it is to be held as a simple diluent. The fluids of the body being exposed to continual expenditure from the tears, the saliva, the secretions poured into the alimentary canal, from the vapour of the breath, the exhalations of the skin, from the urinary and other secretions,—the demand for drink becomes even more urgent than for food. That this is the case, we know from accounts furnished, detailing the horrible sufferings not unfrequently experienced by mariners, as well as from cases recorded of persons who have voluntarily starved themselves to death. Simple water is the only essential drink; all other fluids employed as drinks have, along with water, their chief constituent, substances which may be classified into two orders; the one containing digestible matter, the other incapable of affording nourishment, but which promote the digestion of others, or correct deleterious qualities they may possess. To the former belong mucilaginous, saccharine, and gelatinous fluids; the latter we shall consider along with other condiments.

Condiments.—In a state of health and vigour, simple food and water are all that are required, without the necessity for substances to promote the process of digestion. But where the energy of the organs is impaired, they must be coaxed to perform their duty, or roused into action by appropriate stimulants; or the food may be of such a nature as to require a corrective, in order to effect its proper elaboration; and lastly, the glutton may require stimulants for the purpose of exciting and spurring up his overloaded organs of digestion, so that they may in some way or other dispose of the burden he has imposed upon them. These substances, when introduced into the stomach, are not acted upon; they either traverse the alimentary canal, and are subsequently ejected, or they are taken up without change, and carried into the general system, to be in the course of time removed. Indeed, all substances introduced into the stomach may be reduced to two kinds, the one comprising such articles as are decomposed and digested, the other including all such as resist the action of digestion. The latter may either be inert or active. If they facilitate and promote digestion, or correct injurious qualities of food, they are termed condiments.

Common salt is the only condiment obtained from the inorganic kingdom. It is more universally employed for this purpose than any other substance. Animals take it greedily. In due quantity it conduces to their health, and promotes their being brought into good condition. Wild animals instinctively seek it with great avidity; those of the continents of Africa and America are known to traverse immense tracts of country, overcome vast difficulties, and undergo great fatigue, in order to procure it at the sea-shore. In America there are salt springs, to which great varieties of wild animals resort to obtain it. That these springs attracted animals now extinct, for the purpose of licking salt, appears from the numerous remains of their skeletons around them; hence the name given to these springs, Great Bone Licks.

The utility of salt is proved by a number of facts. An ancient punishment existed in Holland, which consisted in feeding the convicts upon unsalted bread and water alone. The consequences are said to have been so horrible that it was abandoned, the wretched criminals being devoured by worms generated in their own bodies. When the heavy excise duty was imposed on salt, the poor in Ireland, not being able to procure it as a condiment for their miserable fare, an epidemic fever appeared among them, for which common salt was accidentally discovered to act as a certain specific; it was therefore inferred that the disease arose from deficiency of it in their provisions. Why salt should be so necessary appears to be accounted for by the observations of Dr Prout, who has shewn that chlorine, one of the constituents of salt, and a powerful and energetic elementary principle, is essential to the constitution of healthy gastric juice. Soda, another of its constituents, found abundantly in the blood and the various secretions, is derived in all probability from the same source.

Vinous or *alcoholic fluids* have, from the remotest ages, been used by man in every stage of civilization, with very few exceptions. Their stimulating effects depend on alcohol, though their action is modified by various substances they may have in combination, as well as by the quantity of alcohol they may contain. Pure alcohol is a limpid colourless fluid, with an agreeable smell and strong penetrating flavour. It operates upon the animal body in three different ways: *first*, by exciting the part with which it comes immediately in contact; *secondly*, by its influence being transmitted along the nerves; and *lastly*, by its being absorbed and carried along with the circulating fluids, as is shewn by its appearing in the breath soon after being swallowed.

Wines, beer, and other fermented liquors, and the various distilled spirits, are distinguished from each other by substances which they contain, and to which they owe their specific properties. Some of them hold nutrient matter in solution, such as sugar, gluten, and starch; or they may have in combination acids, bitter and astringent principles, and volatile oils, by which their properties are modified and determined.

A healthy stomach certainly requires no prompting, there being no necessity for the use of what Dr Kitchener has called peptic persuaders. The peasantry of Scotland, than whom more robust, vigorous, and active rustics, both in mind and body, do not exist on the face of the globe, employ habitually no other condiment than salt. In fact, every thing else is not only superfluous, but directly injurious. In an artificial state of society, however, it is different. Sedentary employment, protracted and harassing mental or corporeal labour without healthy exercise, impair the tone of the digestive organs. The moderate and judicious use of vinous liquors is in such cases decidedly beneficial, by enabling the organs to perform their duty. When taken so as to produce intoxication, they are poisons; where they are employed to urge the digestion of more food than the body requires, they are prejudicial; and they prove injurious to some constitutions in every quantity and in every form. The condiments derived from the vegetable kingdom are very various; they may be classified as acid, bitter, astringent, and aromatic volatile principles.

The acids used as condiments are acetic acid, or vinegar, citric acid from lemons, and the malic acid from apples. They aid the digestion of crude vegetable food, and rich and oily animal substances are more easily digested by being taken along with these acids. Thus we employ apple sauce with pork and goose, lemon with wild fowl, and vinegar with salmon. Though vinegar occasionally promotes digestion, in excess it destroys the tone of the stomach. Young ladies anxious to be fashionably pale, and afraid of becoming too stout and robust, have frequently taken vinegar in such quantities as to induce even fatal consequences.

Vegetable bitters support the tone of the digestive organs. The infusion of bitter herbs in wine was a very common practice with the ancients. The wholesome quality of malt liquors is in a great degree owing to the bitters employed in their preparation. It has been ascertained that cattle thrive better on pastures where there is a due proportion of bitter herbs. Indeed nature furnishes in the bile a bitter, which from this quality is conducive to the process of digestion.

Astringent substances prove beneficial, where, from concurring causes, such as a warm and moist climate, or the nature of the food, the organs of digestion become unusually relaxed. Hence the natives of India and other warm climates are in the habit of chewing astringent vegetable substances, such as the betel leaves, whereby the debilitating and relaxing tendency of the climate and food is obviated.

The aromatic spices and pungent stimulants employed for the purpose of rousing the action of the stomach and bowels, are exceedingly numerous. The different peppers, cloves, nutmeg, ginger, &c.; the onion tribe, horse-radish, mustard, mint, sage, &c.; to which may be added tea and coffee. Some of these, as onions and nutmeg, have the stimulating principle associated with nutritious matter, but they are chiefly useful in promoting digestion by the excitement which they produce. In hot countries they are required to rouse the flagging appetite, or enable the stomach to digest vegetable diet, which without their aid it might not be fully able to accomplish. In a healthy and vigorous stomach, and with easily digested food, they are worse than useless, by hurrying the process of digestion, and exhausting the tone and excitability of the stomach.

Hunger and thirst are sensations which are excited in animals to warn them when it becomes necessary to take into the system food and drink. The purpose which they serve is consequently sufficiently obvious. Every one must have personal knowledge as to the feelings which characterize hunger and thirst, and from experience possess a more just idea of their nature than words can convey. Numerous conjectures have been hazarded in order to account for the physical cause of these sensations.

Hunger has been attributed to certain mechanical conditions of the empty stomach, as to the friction of the internal folds upon each other, to the pressure of the neighbouring viscera, and to the congestion of blood in its vessels. The form of the stomach is however such that the surfaces cannot rub against each other; and when called into action by the introduction of solid food, were friction the cause, instead of being subdued, it ought to be increased, from the surfaces rubbing against the contents, and from the increased muscular action called forth. Pressure, too, instead of increasing the sensation, allays it. For this purpose the wandering Tartar, when pressed by hunger, places a board over the region of the stomach, and secures it with a belt, which he tightens when necessary, whereby the cravings are diminished. Animals, and even man, when urged by hunger, occasionally swallow substances which are wholly indigestible, for the purpose of appeasing the appetite.

Further, the empty stomach, instead of having a larger quantity of blood in its vessels, has less than when distended with food, and when exerting its full energy during digestion.

Again, it has been attempted to account for hunger by ascribing it to the action of the gastric juice upon the internal surface; but it has been ascertained that gastric juice is not secreted, excepting during the process of digestion; and even if it were, it has no power over living matter. Thus, worms are often found in the stomachs of man and animals, without being acted upon by the juices; whereas, when deprived of life, they would be digested in an hour or two.

Lastly, hunger and thirst have been ascribed to the condition of the nerves. That the nerves are the channels by which these sensations are transmitted to the seat of perception, is true; and therefore if the nerve proceeding from the brain to the stomach be cut, or tied, so as to interrupt the communication between them, there remains no means by which the conditions giving origin to these sensations can be announced. In a dog, which had been starved so as to render it ravenously hungry, the nerves proceeding to the stomach were cut; instantly the dog displayed perfect indifference to food; and when presented with it, continued to eat till the stomach was enormously distended. The stomach having been paralyzed, neither the necessity for food, in the first place, nor when a sufficiency had been taken, in the second place, could be announced.

The condition of the mind also affects these sensations. Let a person ready to partake of a favourite meal with the keenest appetite, the result of fasting and exercise, be suddenly informed of some calamity that has occurred, in which he is deeply interested, and in a moment all feeling of hunger vanishes. Increased thirst, on the other hand, is a frequent consequence of impressions made on the mind, operating on the body. Diseases, and several medicinal substances, such as narcotics, destroy the appetite; and therefore the sensation of hunger is not experienced; while, on the other hand, that of thirst is generally much increased. This affords one of the examples so abundantly furnished by the animal body, of adaptation to circumstances. In such a disease as fever, the digestive organs are not adequate to their duty. If food be introduced, it cannot be acted on in a proper manner, but is hurried into decomposition, and produces a corrupted mass, which tends to keep up and aggravate the disease. From fluids being taken up immediately, without the necessity of undergoing change by the action of the stomach, they are craved and are taken not only with impunity but with advantage, in order to preserve the blood sufficiently diluted, and supply the loss sustained by the secretions. The aversion to food therefore, and the loathing which its very appearance excites, while there is an increased desire for drinks, are wise and beneficent provisions.

On the whole, the explanations as to the proximate cause of hunger and thirst which have been suggested, are by no means satisfactory. They evidently belong to that class of impressions imposed on organized bodies by the Creator, which conduce to important and useful purposes.

The fibres of the muscular coat of the stomach are arranged in longitudinal, transverse, and oblique directions, whereby the contents are completely embraced. The blood-vessels are large and numerous, and are so distributed as to admit of great variations in the quantity of blood they transmit. Besides being supplied with nerves from the same source with the other portions of the elementary canal, the stomach receives two nerves, by which it is brought into more immediate connexion with the brain.

We have already considered the changes the food is subjected to previous to its introduction into the stomach, and therefore have now to examine the effects produced by the agency of this organ. These effects result from the temperature to which the mass is exposed, the motion to which it is subjected, and the changes produced upon it by the gastric juice, whereby it is converted into a peculiar substance, termed chyme. Chymification, which is the result of the changes the food undergoes, is only one step, though an important one, in the process of digestion. The popular notion that digestion begins, and that it is completed in the stomach, is far from being correct: the process as a whole commences on its first introduction into the mouth, and is not perfected till the new matter is converted into arterial blood in the lungs. Chyme is a soft pulp, of an acid quality, which is owing to the presence of free muriatic acid, generally of a grey or ash colour, somewhat sweet, though frequently insipid, and without any peculiar smell. Its properties, however, vary according to the nature of the food from which it has been derived.

Digestion in the stomach has been ascribed to trituration, to a concoction analogous to cooking meat by stewing, to fermentation, and to solution. It is very true that the food does undergo changes which are somewhat like these mechanical and chemical processes, but by no means identical with them. On the introduction of a meal into the stomach, its presence calls forth the action of that organ, an increased determination of blood takes place towards it, the gastric fluids are poured in more abundantly, and the muscular action is roused.

The length of time required for chymification varies much according to the state of the individual, and the nature of the food. About four hours is considered the average time required for digesting a full meal. The food is exposed in the stomach to the action of a secretion which has been ascertained to be furnished only during the process of digestion, to which the term gastric juice is especially restricted. This liquor is not the product of glandular organs, but is poured out immediately from the blood-vessels. The gastric juice, according to the discovery of Dr. Prout, confirmed by others, contains a portion of the elementary body chlorine, so termed from its greenish-yellow colour. Chlorine is a gaseous substance of energetic action, having a considerable affinity for water; with hydrogen it forms muriatic acid, or the spirit of salt: hence the source of the muriatic acid found in the gastric juice, and hence, too, the acidity of healthy chyme. Excepting from the existence of chlorine, the gastric juice would not appear to differ much from the saliva. But when we examine its properties, and the results of its action, we must acknowledge it to be by no means an inert substance. When it is recollected that "a little leaven leaveneth the whole mass," we may easily conceive how the gastric juice may be the cause of commencing important changes in the food.

Its power of coagulating milk and albuminous substances is another of its striking properties; and so efficient is it in this way, that it has been ascertained that six or seven grains of the rennet of a calf, dissolved in water, will coagulate upwards of a hundred ounces of milk; and afterwards, by its solvent power, it again dissolves the coagulum, which peculiarly distinguishes it from other substances possessing the property of producing coagulation.

Digestion was at one time compared to putrefaction, but by the term putrefaction must have been understood something very different from what it implies now, for the gastric juice is not only a powerful antiseptic, but even renders substances sweet which have partly undergone this kind of decomposition. Spallanzani found that the gastric juice of a dog will preserve veal and mutton perfectly sweet, and without loss of weight, thirty-seven days in winter, whilst the same meats immersed in water emit a fœtid smell as early as the seventh day, and by the thirtieth are resolved into a state of offensive putridity. It has been ascertained that the most offensive meats that dogs can be induced to swallow, are in a short time rendered perfectly free from putridity. Among mankind meats are often kept till they become highly offensive to the sense of smell, in order to render them tender, mellow, and of easier digestion. Various kinds of game and venison, for example, are often presented at table in a condition which nothing but fashion and custom could tolerate, and yet almost instantly the putrid mass is sweetened by the contact of the gastric juice.

Various fluids possess different solvent powers. Thus, water dissolves gum, but not resin, while alcohol will dissolve the latter, but not the former. In like manner, the gastric juice possesses proper solvent power over substances, independently of their texture and density. It exerts no action on living matter, and therefore worms exist in different parts throughout the whole extent of the alimentary canal, and seeds traverse it, without having the germinating property injured, but rather quickened, as occurs with corn when taken into the stomach of the horse without having been bruised and killed previous to introduction: it springs up rapidly on the dunghill. In the same way the seeds of many plants pass through the bowels of frugivorous animals, with advantage to their subsequent germination. In a similar manner it has been conjectured that the eggs of fish may be transported by birds, whereby new made ponds become stocked with them. If gastric juice be present in the stomach when death takes place, it then acts upon the coats, so that the stomach is digested by the liquor furnished by itself. This takes place when an animal is killed after a meal, while the process of digestion is going on. It has frequently been observed in criminals, where they have taken food immediately previous to execution, and has been noticed where sudden death has occurred from accident during digestion. In the great majority of cases, death takes place when the stomach is free from gastric juice, as in natural death, where the function of digestion is abolished sometime before decease.

The above coagulating, antiseptic, and special solvent powers peculiarly distinguish the gastric juice; but besides, it is found to vary, not only in different animals, but in different individuals, and in the same individual at different times, under various conditions of health and other circumstances. The gastric juice of a carnivorous animal readily acts on flesh, but produces little or no impression upon vegetable matter; while in herbivorous and granivorous animals, it dissolves the latter, but refuses to act on the former. In a suckling, milk is immediately coagulated, and speedily re-dissolved, which does not occur readily in the adult. In the same way are to be accounted for variations depending on the habit and custom, the peculiar constitution and state of health of individuals.

From the gentle undulatory motion produced by the muscular coat, the mass of food is kept in motion. It is, however, not of that violent kind which has been compared to churning, for by such agitation a portion would be brought in contact with the surface of the stomach for an instant, and again removed. Neither is the food disposed in the stomach in an indiscriminate mass, nor in the order in which it may have been swallowed. On opening the stomach of one who has died from repletion after a gluttonous feast, the soups, the fish, the various stews and roasts, with the puddings, tarts, and other articles innumerable, are not found layer upon layer as they were devoured. The most easily digested occupies the surface, in immediate contact with the inner coat of the stomach, and thus becomes bedewed with the gastric juice, and converted into chyme. The more intractable part is placed in the centre, and thus is longest exposed to preparatory influences, so that when presented at last, it yields to the action of the solvent liquor, and, in its turn, is chymified. Digestion, therefore, does not take place simultaneously throughout the whole mass, but is only perfected in that which is in immediate contact with the stomach. If fresh food be introduced into the stomach before the previous meal has been digested, it becomes coated over with that which has been for sometime lodged, so that the recent portion is placed in the centre, like the least digestible parts of a single meal.

It is by the action of the muscular coat that the food is disposed in regular order, and brought in succession under the power of the gastric juice. By the same muscular action the chyme is carried onwards to the pylorus, where, if found properly elaborated, it is permitted to enter the intestine; if not, the pylorus is irritated, contracts, and shuts the passage into the bowels. Muscular action at the sametime is called into play, so as to throw the food back again by what is termed antiperistaltic motion; and this may occur again and again, till the valve of the pylorus is satisfied. The irritation of the pylorus may be so great, the call on the muscular coat so urgent, and the sympathies brought into action so extensive and violent, that the offensive matter is ejected altogether from the body by vomiting. Here we have a beautiful and striking instance of design for the most important ends, which nothing but supreme knowledge and power could have foreseen and provided for. By the peculiar tact and sensibility with which the pylorus has been endowed, it is enabled to judge when the matter is fitted for entrance into the intestine, preparatory to its introduction into the general system. It acts as a watchful guardian; and if not satisfied, rejects the matter presented to it, and causes it to be thrown back, that it may be properly prepared; or if it be of a highly offensive nature, calls forth powers by which it is entirely ejected. Insoluble and inert substances it however suffers to pass the barrier. Thus the seeds of plants, metallic and other indigestible matters, are permitted to enter, to be subsequently thrown out. Even by frequent application, it at last yields to other substances, such as medicines, &c. which are thus allowed to get into the bowels.

The following, then, are the occurrences which take place in the stomach:—Aided by the temperature, the gastric juice dissolves the food, that which is most easily affected being first acted on. The pulpy chyme, of the consistence of thin gruel, is then, by the muscular coat, carried and presented to the pyloric orifice, through which it passes into the intestine, where it is subjected to further change.

The first portion of the intestinal canal, as has been already mentioned, is termed duodenum, beyond which the smaller intestine is divided by anatomists into two portions, the first named jejunum, the second ilium—an unnecessary division so far as their structure and functions are concerned, for in these respects there is no distinction between them. From the pylorus of the stomach onward to the cœcum, which forms the commencement of the great gut, the canal becomes gradually contracted; the lining membrane, or internal mucous coat, is folded into transverse plaits, which are larger and much more numerous in the upper than in the lower portion. It presents a villous or shaggy surface, like the nap of velvet, formed by the termination and commencement of blood-vessels; and over its whole extent there are numerous glandular crypts, either scattered singly or disposed in groups, which pour out sufficient mucus to preserve the surfaces smooth and slippery. There is also a fluid exhaled immediately from the arteries, named intestinal juice, which, so far as has been examined, appears to possess properties similar to the gastric secretion.

The duodenum is the most capacious portion of the smaller intestine. In proportion to its length, the mucous folds are numerous and large. It is only covered by the peritoneum anteriorly, and connected to the vertebral column behind by loose cellular membrane. It is exceedingly dilatable.

The chyme does not flow into the duodenum in a continuous stream, but at intervals, being introduced by the slow undulatory motions of the stomach, and carried onwards by similar motions in the duodenum. These movements do not uniformly take place in the same direction, but slight retrograde motions also occur, so that the same portion of pulp is repeatedly presented to the same surface, which is thus gently rubbed over it.

It has been already mentioned, that the duct from the liver conveying the bile, and the duct of the pancreas, terminate in the duodenum. The presence of the chyme induces a flow of these secretions, just as sapid substances in the mouth cause the saliva to be copiously poured out. At the same time, the secretion from the surface of the duodenum itself exudes more abundantly. The chyme, therefore, comes in contact with three different fluids. The alkaline bile neutralizes the acid chyme; it also appears to combine with the more oily portion of the chyme. The pancreatic fluid, as far as it has been examined, abounds in an albuminous fluid, which is supposed to be of essential importance in animalizing the chyme derived from vegetable food in particular. The part performed by the intestinal juice in the changes which take place in the chyme in the duodenum, has not been ascertained; but the important results effected through the action of the gastric juice prepare us to admit, that most probably they are neither small nor unimportant.

The result of the changes effected in the duodenum is the evolution of two products, the chyle and the recrementitious part. The chyle is a coloured fluid having a considerable resemblance to cream; it has a sweet and somewhat saline taste, and begins to shew an analogy to perfect blood. Like blood, it separates into a coagulum or clot, and a colourless serum. It differs from blood in the albuminous matter being as yet imperfect, in the presence of oil or fatty substance, and in the absence of fibrin and proper colouring matter. The chyle is taken up by the absorbents, which commence on the surface of the intestine: from conveying this milk-like fluid, they are termed the *lacteal* absorbents. The lacteals are more numerous in the duodenum and upper portion of the smaller intestine, and become fewer at the lower part of the gut, in accordance with the less extensive surface from which they arise, and the diminution of the nutritious fluid which they have to take up. Before the contents of the bowels reach the cœcum, the whole of the chyle has disappeared, none being ever seen beyond the small intestines, excepting where the matter has been preternaturally hurried through, either from the exhibition of medicine, or from diseased condition of the canal.

The bile attaches itself more especially to the recrementitious portion, and gradually becomes mixed up with it, imparting its colour and bitter taste. The bile, besides being subservient to the changes which occur in the duodenum, serves as a stimulus to the bowels, exciting the peristaltic movements, and promoting the progress of the contents. Where an excessive secretion of bile takes place, a purgative effect results; whilst its deficiency or obstruction is followed by a torpid and constipated state of the bowels.

When the recrementitious matter reaches the cœcum it meets with new secretions, and is subjected to farther changes. The caput cœcum, the blind or shut head of the great gut, is fixed down in its situation. The small intestine which terminates here protrudes in such a manner as to form a valve, named the iliac valve, by which, in the perfect state, any return of matter is effectually prevented. Attached to the cœcum there is a small vermicular appendage, which is abundantly supplied with secretions. It has been ascertained that here the residual matter again becomes acid; besides, a peculiar volatile principle is poured out, which imparts the characteristic odour to the contents of the great gut. It is in the cœcum that the last effort of digestion takes place, and the first step of fecation commences. It has been stated, that in several herbivorous animals the cœcum and colon are more capacious than the whole of the rest of the alimentary canal. Whatever matter remains capable of furnishing nourishment after traversing the upper portions, and being mingled and acted upon by the different secretions, is now subjected to the action of these parts, and the secretions which are poured into them; a second chymification occurs, and a separation is effected between what may be taken up with advantage to the system, and that which is excrementitious, to be subsequently discharged, along with the excretions of the alimentary canal.

The matter poured into the cœcum is of a soft pultaceous consistence. The colon is so contracted by three longitudinal musculo-membranous bands, as to form cells. In these cells the contents are lodged till the more fluid and nutritious parts are absorbed, and the consistent excrementitious matter alone remains. By the action of the muscular coat, powerfully aided by the longitudinal bands, the consistent residue is pushed onward, and finally discharged by the rectum.

The chyle being absorbed by the lacteals, is conveyed by them through a series of small lenticular-shaped bodies, varying in size from a pin's head to that of half a cherry. These bodies are termed the mesenteric glands. They differ from the glands which separate from the blood peculiar fluids, by having no excretory ducts. They are abundantly supplied with blood-vessels, which are curiously convoluted and interlaced with each other, so as to admit of considerable congestion. As the lacteals approach one of these glands, they divide into numerous branches, which enter it, and are there interwoven with each other, and with the blood-vessels. Again, a number of small vessels proceed from the opposite margin, unite to form larger, and convey the chyle out of the gland; and this may be repeated through three or four of these glandular bodies, till at last the chyle brought by these various intricate channels is poured into one common tube, the commencement of which is swelled out into what is termed the receptacle of the chyle. This receptacle lies in the front, and somewhat to the right of the aorta, at the upper part of the cavity of the abdomen. Becoming contracted into a cylindrical tube, named thoracic duct, it enters the chest, proceeds upwards, and crosses to the left side, where it pours its contents into the stream of venous blood proceeding to the heart, where the internal jugular vein from the head and main vein of the arm meet under the collar bone, to form the left branch of the descending cava.

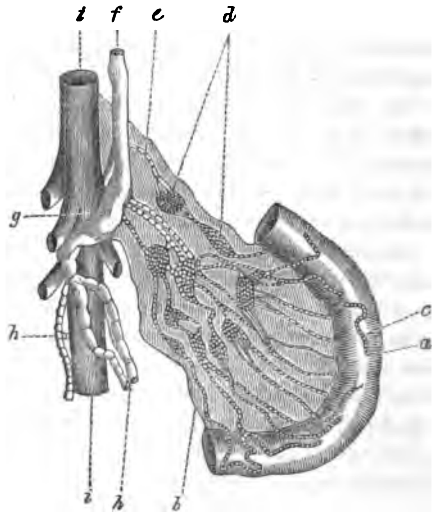

FIG. 14.

In the engraving *a* represents a portion of intestine; *b*, the mesentery; *c*, a lacteal arising from the intestine; *d*, mesenteric glands; *e*, a lacteal, after having passed through two glands; *f*, thoracic duct; *g*, the receptacle of the chyle; *h*, lymphatic absorbents, proceeding upwards to pour their contents also into the receptacle; *i*, the aorta.

The chyle in the receptacle and thoracic duct is found to approach still more closely to perfect blood than when first taken up by the lacteals. The albumen is more complete, fibrin appears, and small coloured globules of a light pink colour are seen in it. These changes have been effected in its transmission through the glands, and from the slow progress through them, in consequence of the intricacy of the vascular distribution, there is time afforded for its more complete elaboration, and for admixture with fluids from the blood-vessels. All the lacteals do not however terminate in the receptacle and thoracic duct; some of them join branches of the vena portæ, either in the glands, or after having passed through them, whereby they are carried to the liver.

When the chyle mixes with the red blood, we soon lose all trace of it. It has been noticed as far as the right auricle of the heart, but the agitation to which it is exposed along with the blood in the right side of the heart, produces more complete intermixture. And lastly, on being transmitted to the lungs, it undergoes its final completion: by the exhalation of superfluous water, the discharge of carbonic acid, and the attraction of what is necessary from the atmosphere, it now becomes perfectly arterialized blood.

When we take a general view of the function of digestion, we find that it consists of a number of distinct acts, each of which are necessary to the perfection of the process, and failing any one of them, the necessary change on the aliment is incomplete. We have seen, from the first introduction of food into the mouth till the process is perfected, that various secretions immediately poured out from the blood-vessels are added to the new matter, so as to form a mixture between new and as yet crude materials, and fluids assimilated to the constitution of the individual, indeed forming a part of his body. We have seen that at each stage there results from the union a third matter, which product is not a mere solution in the fluid, as where salt is dissolved in water, nor a mere mixture where the constituents may be again separated, and presented in their original form, but a new formation, modified, it is true, by the nature of the food, and the character and condition of the secretions which are added.

Of these processes the first that came under our notice were the changes effected in the mouth, consisting of assimilation of temperature, trituration, and insalivation. The second occurred in the stomach, where the food remains for a sufficient time, in order to undergo the process of chymification. The third took place in the duodenum, where chyle is elicited. In the fourth the chyle is taken up by the lacteals, transmitted through the mesenteric glands, and conveyed into the thoracic duct, where it presents characters similar to those of the blood. In the fifth and last stage, it is mixed with the red blood, and along with it sent by the right heart to the lungs, where it is perfected into arterial blood.

In all these processes, vital agents are called into action, the effect of which is the production of a vital fluid adapted to the various purposes for which it is required in the system. But even in our artificial processes many striking alterations are effected, and remarkable products obtained: for instance, in the successive changes which occur in the conversion of the mild nutritious starch into the pungent stimulating ether. Here we find, in the first place, on the addition of a little ferment, with exposure to a proper temperature, air, and moisture, that the starch is changed into sugar; secondly, by further management and regulation of heat, the sugar is converted into alcohol; and lastly, by adding an acid, aided by heat, the alcohol in its turn is formed into ether.

Hitherto we have followed those materials which are actually digested, and so altered that their original properties entirely disappear, to be replaced by new qualities and characters of the product. But drinks, with several substances taken along with the food, as well as medicinal agents, gain entrance into the system without suffering decomposition, and without having their physical properties affected. We now proceed to consider by what channels these are introduced.

Drinks, from being taken more rapidly than solid food, and immediately transmitted to the stomach, have their temperature assimilated chiefly in that organ. Cold fluids may therefore be the means of reducing the internal temperature, whilst hot drinks impart heat to the body. Water being absolutely necessary to preserve the blood in a proper state of dilution, in consequence of the incessant loss it is exposed to from transpiration, internal exhalation, and secretion, it is consequently urgently demanded, and we are informed when it becomes necessary to introduce it by the sensation of thirst. Soon after reaching the stomach it gradually disappears, even when prevented from passing into the intestine by securing the pylorus with a ligature.

Although the absorbents arising from the stomach and intestinal canal are exceedingly numerous, it is now ascertained that they do not form the only channels by which nutritious matters enter the system, nor do all the absorbents from these parts terminate in the thoracic duct, several of them pouring their contents into the branches of the vena portæ. The veins collecting the blood from the alimentary passages, not only return the blood conveyed to these parts by the arteries, but also perform the office of absorbents, and carry off especially such substances as are not altered by the powers of digestion, and converted into chyle. The lacteal absorbents appear to be endowed with the power of selection, taking up chyle, but refusing to receive other matters; whilst the veins are less particular as to the nature or qualities of the materials they drink up. There are accordingly two sets of agents employed in receiving and conveying substances from the alimentary canal. First, the absorbents, which either transmit their contents through the mesenteric fluids into the receptacle of the chyle and thoracic duct, or join veins without entering glands, or while they are distributed through the glands, and lastly after they have again emerged from them. The branches of the vena portæ of the abdomen constitute the other set by which absorption is performed. As has been stated in the chapter on circulation, these veins unite and form one trunk, which proceeds to the liver, where it divides and transmits its blood through that viscus, after the manner of an artery, that is from trunks to branches.

Drinks not being subject to alteration, either before or subsequently to their absorption, are immediately introduced into the sanguiferous system. If they contain nutritious matter, it remains in the stomach while the fluid part is removed, in order that it may be digested; so that, as has been already stated, soups and other nutritious liquids have their fluid parts removed before they are acted upon. In the same way the drinks we take along with our meals are carried off before digestion is commenced, or at least before it is completed.

The body is not constituted so as to admit with perfect impunity sudden or instant change, but if time be afforded it possesses admirable powers of adaptation, so as to suit varying circumstances. A comparatively small quantity of blood taken from a large orifice in a blood-vessel may produce fainting, whilst a large portion may be withdrawn without such effect, if the blood-vessels have time to accommodate themselves to the diminished quantity in the system. Many causes tend to subvert the balance between the blood of the internal cavities and that of the external surface and extremities. Cold impels the blood to the internal parts, while it astringes the vessels of the surface. Heat, on the other hand, produces a relaxation of the integuments, and promotes the flow of the blood from the deep-seated organs. Disease affords numerous examples of subversion of balance, where local congestion takes place in some parts, and deficiency in others. Ague affords a striking instance of this: in the cold stage the blood leaves the surface, the skin shrinks, the countenance becomes pale, and the extremities cold, but in the hot stage the face becomes suffused, and the whole surface hot and turgid.

Now, when a large quantity of drink has been taken, and rapidly carried off from the stomach, the minute, convoluted, and tortuous absorbents are not calculated to afford a sufficiently capacious and ready entrance, while the veins are adequately voluminous for this purpose. Yet the veins from the stomach and intestinal canal, though sufficient for the conveyance, cannot contain any considerable quantity of fluid, or admit of much accumulation; and further, the vena portæ distributed through the dense substance of the liver, is both incapable of much distension or of rapid transmission.

The spleen is now generally admitted to be the organ which serves as a reservoir of fluids, till they can be conveniently introduced into the system. In proportion to its bulk, it is the most vascular organ in the body; its artery is very large, and the veins numerous and capacious; the absorbents also are abundant. Indeed, it may be considered as a congeries of blood-vessels, with little or no intervening tissue. That these different vessels freely communicate with each other is proved from the facility with which injections flow from the artery into the veins, and also into the absorbents. It has been ascertained that coloured fluids and odorous substances have found their way into the vessels of the spleen, when introduced into the stomach, without having passed into the intestinal canal, and that during digestion, especially where much fluid has been taken, the spleen is swelled. During the cold fit of an ague the spleen is found to be enlarged, from distension of its vessels, and when a patient has long laboured under that disease, a permanent enlargement of this viscus takes place.

It is therefore concluded, in the first place, that the spleen serves as a reservoir, in which fluids may accumulate till they be carried off by the returning vessels, the veins carrying them towards the liver on the one hand, the absorbents conveying them to the thoracic duct on the other, so that they are thus more or less rapidly introduced into the general circulating mass according to the wants of the system. Secondly, when the blood is impelled from the surface towards the central parts, as on exposure to cold, or during the cold stage of an intermittent, the construction of the spleen readily permits accumulation of blood to take place in it without inconvenience, and in this way prevents other organs from being oppressed by congestion, which neither their structure nor function can bear with impunity. The spleen in this manner seems as a kind of safety valve to the sanguiferous system, to divert the fluids of the body under particular circumstances, and therefore must be considered as an important conservative organ. Notwithstanding the useful purposes to which it may conduce, it does not appear to be absolutely essential to life, or rather its functions may be vicariously performed by others, for it has frequently been removed from the lower animals by way of experiment, and after recovery from the operation, the system, as far as has been observed, does not appear in any respect to suffer.

The spleen being classed along with the glands, and as the term gland is apt to suggest the idea of an organ subservient to the separation of a peculiar fluid from the blood, innumerable attempts have been made by dissection, experiment, and conjecture, to ascertain what it secretes. The most careful search has failed in detecting any thing like an excretory duct, such as we find the salivary glands, the pancreas, liver, &c., to be supplied with; but it is to be recollected that all those organs furnished with ducts separate from the blood fluids which are not intended to be reintroduced into the system, and several of them are altogether excrementitious. From the free communication which is established between the arteries, veins, and absorbents of the spleen, an interchange of fluids may be readily effected, and the drinks be thus partly assimilated before further introduction into the body. The numerous absorbents proceeding from the spleen to the thoracic duct are found to convey a fluid of a reddish colour, and coagulable, which mixes with the contents of the thoracic duct. A change analogous to that which the chyle undergoes in passing through the mesenteric glands, appears thus to be effected upon the fluids transmitted through the spleen. Upon the whole, we are warranted in concluding that the spleen serves as a reservoir for drinks till they can be opportunely introduced into the system, and also allows a congestion of blood under peculiar circumstances, so as to admit of alteration in the balance between the quantity of blood on the surface and in the internal organs; and further, that while these fluids remain in this viscus, or during their transmission through it, they are so elaborated as to be prepared for reception into the general circulating mass. As has been stated, these purposes are not absolutely essential, or other organs may vicariously perform them, since the spleen may be extirpated without much apparent inconvenience to the animal.

Colouring bodies, odorous substances, various medicinal and chemical agents, pass along the stomach and intestinal canal, and are received into the general circulation without suffering change, or with only slight alteration of properties. When animals are fed on food mixed with madder, the bones, cartilages, and membranes become of a pink colour; the colouring matter of that root entering capillaries which are too minute to admit the red particles of the blood. Soon after rhubarb powder has been swallowed, the urine becomes tinged with yellow from that substance, which has thus passed from the stomach to the kidneys without change. Various bodies, characterized by their peculiar odour, enter the system, and that too in a very short time after being swallowed. Thus, garlic, onions, and spirituous liquors, are soon detected in the breath, having passed from the digestive organs without alteration. The oil of turpentine, a few minutes after it has been taken, imparts to the urine the exact smell of sweet violets.

Medicinal articles are generally exhibited by the mouth in this way; their subsequent action depends upon their immediate effect upon the mucous membrane lining the stomach and intestinal tube, or on the action being transferred to distant parts, or to the whole system, through the medium of the nerves; and lastly, they may be taken up and introduced into the blood, and subsequently make their appearance in one or other of the secretions. For example, many find their way to the kidneys, and produce an increased flow of urine; some are determined to the skin, promoting transpiration and inducing sweat; others direct their action to the lining membrane of the air-passages, and facilitate expectoration, while others exert an influence more or less marked upon the body at large. Sulphur, when taken internally, shortly discovers itself by the odour it imparts to the breath and emanations of the skin. When mercury has been exhibited for some time in any quantity, it displays its action on various secreting organs, and exerts an influence directly or indirectly on every organ and tissue in the body; in some instances it has shewn itself by silvering coins, or the watch in the pocket, or rings and other ornaments worn by a person undergoing what used to be called a course of mercury. In these instances it unites with the other metals, as gold and silver, forming what is termed an amalgam. In other cases it has been observed deposited in its metallic state, even when taken in another form, shewing that it had suffered reduction in the system. Several salts pass from the stomach into the circulation, and are again expelled without suffering decomposition or change. This is the case with saltpetre or nitrate of potash, for on evaporating the urine of an individual who has previously taken doses of this salt, it is found in a proportional quantity in the residue. Several other saline substances may be shewn to pass by the same channel, and with similar integrity, as proved by their appropriate tests and reagents; others again are altered or decomposed either while in the stomach or intestines, or after they have been absorbed. The salts of iron, from the facility with which they are decomposed by tannin, the astringent and tanning principle of most vegetables, are often reduced to the tan-gallate of iron, the colouring matter of ink. When exhibited as medicine, and when they meet with tannin and gallic acid in their course, either from the food or other medicines which may have been taken during their employment, the discharges become of a black inky colour, frequently to the no small alarm and consternation of the patient and his friends. Calomel, which is composed of chlorine and mercury, is also liable to be changed in the bowels, by meeting with substances capable of acting upon it. Of these sulphuretted hydrogen is one, a gas which, in some diseased states of the intestine, especially of the colon, is generated in considerable quantity. When calomel is exposed to this gas, it is converted into a black substance, which imparts a dark colour to the alvine discharges. Some physicians, ignorant of this fact, have recommended that the calomel should be continued as long as dark-coloured discharges are produced. Now, in such cases sulphuret of mercury is the cause of that colour, and as long as the cause continues, so long will the effect. Various alkaline salts, formed with the vegetable acids, are liable to decomposition, the alkali and the acid being separated either in the first passages or in the course through the circulation, or lastly, while being excreted from glands, especially the kidneys. This is apt to occur where potash or soda is combined with carbonic, acetic, citric, and tartaric acids.

We have already shewn that chyle is taken up from the intestinal canal by the lacteal absorbents, and conveyed to the thoracic duct, but that occasionally a little of it may find its way to the liver, either in consequence of some of the lacteals having joined branches of the vena portæ, or from these veins themselves acting as absorbents;

for, as we have stated, the lacteals appear to exercise the power of selection or choice with respect to what they receive. The veins, on the other hand, are much more indiscriminate in what they take up. Now there is a wise provision in this; for whatever the absorbents receive, they must convey into the general mass of circulating fluids, although it may be retarded or modified in its course; but when any substance has been absorbed by the branches of the vena portæ, there is a subsequent opportunity for its being cast out, while the contents of the porta are filtered through the liver. In this way the liver acts as an important organ in connexion with digestion and sanguification, and thus not only is the bile secreted in order to be subservient to chylification, and to stimulate the peristaltic motion of the bowels, but the liver acting as a strainer in the formation of bile, drains off from the venous blood what might have proved highly noxious; and hence the total suppression of the action of the liver speedily proves fatal.

It has been stated that drinks are rapidly taken up after their introduction, that they are not subjected to alteration previous to absorption, and that the veins from the stomach and intestines appear to be the chief agents of their removal. They are in this way mixed with the venous blood, instead of being immediately taken into the absorbents. It has been farther stated that the spleen is calculated to admit of considerable accumulation of fluids, that a very large quantity of blood circulates through it, that after a meal it swells, and that the numerous absorbents arising from it, and terminating in the receptacle of the chyle and the thoracic duct, convey a coloured fluid, displaying several of the characters of more perfect blood. Fluids, therefore, enter the circulation from the alimentary canal, pursuing three different routes in their passage; first, directly to the liver, through the veins, mixing immediately with the contents of the veins; secondly, they may be arrested for some time in the spleen, where certain changes may be effected upon them. Besides, their slow introduction being partly insured in this way, it becomes more in accordance with the gradual changes which occur in organized bodies in general. From the spleen one portion flows by the absorbents to the thoracic duct, the other is conveyed by the porta, and filtered through the liver. It may be observed that as the porta is the only vein which appears expressly intended to convey new materials into the general system, so is it the only one which discharges from its blood a secretion whereby an opportunity is afforded of throwing off what might have been superfluous or noxious; and, as just now observed, the bile may thus far be considered as excrementitious.

Colouring, odorous, medicinal, and chemical substances, such as have been adverted to, though occasionally observed in the absorbents, are principally carried off by the veins through the liver. The speedy appearance which some of them make, as garlic and alcohol, in the breath, and turpentine and prussiate of potash in the urine, has led to the inference that such matters may enter the circulation, and be conveyed more directly to those parts than by the more circuitous course through the heart and arteries. The observations, however, are as yet too few and indefinite to warrant any certain conclusions from them.

To recapitulate, the chyle enters by the lacteal absorbents, to be carried into the thoracic duct, and by the veins to be conveyed into the system chiefly through the spleen; and all those substances which find their way into the circulation without change, and which are characterized by their peculiar qualities, such as their colour, odour, chemical properties, or the effects they produce upon the body, being taken up by the veins, are introduced principally through the liver.

CHAPTER IV.

THE BLOOD.

Blood—Physical Properties of—Colour—The Red Globules—Their Form and Constitution—Smaller and more numerous in Mammalia—Odour—Characteristic of the Animal to which it belongs—Consistence—Temperature—Specific Gravity—Quantity of in the Body—Coagulation—Relative Proportion of Serum and Clot—Serum—Fibrin—Oil of the Blood—Table of Analysis of—Vital Properties.

One of the most characteristic properties of organized bodies is the power which they possess of appropriating to themselves foreign matter, and so altering it as to adapt it to their various necessities in the growth and nourishment of their own individual structures, and for the continuance of their race.

In the last chapter we have treated of the various successive steps which occur in the conversion of food into a fluid in its most perfect state of adaptation to the highest organized beings. The name blood is applied to this elaborated fluid in animals, the term sap being employed to designate the corresponding fluid in plants. We have noticed what a multiplicity of organs and complexity of apparatus are engaged in forming and perfecting the arterial blood, the characters of which we have now to inquire into.

The examination of this interesting and important fluid may be conveniently conducted under the following heads: *first*, its physical properties; *secondly*, its chemical constitution; and *thirdly*, its vital characters.

The physical properties may be considered in respect to its colour, odour, consistency, temperature and specific gravity.

Colour.—The blood of vertebrated animals contains particles termed the red globules, to which its colour is owing. These globules have excited much interest, and great attention has been paid to them, with the view of ascertaining their nature and constitution. Nevertheless much discrepancy of opinion exists as to their real character. They are said to consist of a central nucleus, with a thin vesicular covering. In the human subject, when examined under the microscope, according to some they are spherical; by others they are held to be oval or elliptical: some describe them as being flat, like a shilling, or of this form with a hole in the middle: others, again, represent them as of no determinate shape. The greater number, however, describe them as being spherical in man, and elliptical in the lower animals. Equally discordant are the accounts furnished by different observers as to their size—the statements varying from the $\frac{1}{1700}$th to the $\frac{1}{5000}$th of an inch in diameter. It is said that they are smaller in birds, and larger in fishes than in mammalia. They are certainly larger than the particles of colouring matter in a number of vegetable substances; for when animals are fed with food intermixed with madder, their bones, membranes, and cartilages become tinged with the colour imparted by that root, shewing that it enters the vessels of these tissues, which exclude the red globules of the blood. Individually, they are colourless, reflecting colour only when in the aggregate. This is, however, the case with most, if not every kind of matter, a single insulated particle being colourless, while in the mass the appropriate colour is displayed. The size of the globules excludes them from the minute capillary vessels, which are of such a diameter as to admit the transmission of merely the transparent and colourless part of the blood. Or perhaps it may be stated more correctly, that in the healthy condition a single globule alone can pass from the arterial to the venous capillaries, so that during the passage of the blood through these minute tubes, its colour disappears, and again becomes evident in vessels of such a diameter as admit of a sufficient accumulation of the globules.

In diseased states many vessels become capable of transmitting red blood, which, in their healthy condition, they exclude. For example, the white of the eye speedily becomes bloodshot from injury, and numerous vessels appear in a very short time to start into existence. This change with respect to the blood-vessels is one of the most usual and characteristic concomitants of inflammation; many organs which are white and colourless in health becoming red when affected with it. There are organs, however, the vessels of which are so exceedingly minute that they exclude the red particles at all times, even when they have for some time been subjected to inflammation, as is the case with the transparent parts of the eye, and some delicate internal membranes, where a loss of transparency is the only change they undergo.

The quantity of colouring matter in proportion to the whole mass of blood varies in different classes of animals. In mammalia and birds it bears the greatest proportion, a smaller in reptiles, and still less in fishes. In the two last classes, namely, reptiles and fishes, the red blood is chiefly confined to a few internal organs, as the heart, liver, kidneys, lungs, and gills. If the statement be correct, which there appears to be no reason to doubt, the larger size of the globules will partly account for this. Their flesh is consequently white, and apparently bloodless. In mammalia and birds great differences in this respect arise from a variety of circumstances. The flesh of wild animals is generally of a darker colour than that of the domesticated. Animals of the chase, after a long run, bleed sparingly, the blood having been impelled into the minute capillaries. It is said that butchers occasionally have recourse to the practice of driving their cattle furiously, and running them for some time before killing them, in order to increase the weight of the carcass, experience having taught them that this takes place; in such cases a much less quantity of blood is drawn, and the flesh presents a dark and somewhat carrion-like appearance. It may be noticed, that in moor game the large mass of flesh upon the breast, forming the powerful muscle so vigorously brought into action in striking the wings against the air during their flight, is of a dark colour approaching to brown, while the deep-seated layer is pale, having merely to raise up the wing against a less degree of resistance. The quantity of colouring matter also varies, not only in different individuals, but also in the same individual at different times, according to age, health, and other circumstances.

During every moment of our existence the globules are incessantly undergoing changes in the two sets of capillaries respectively. When treating of the effects of respiration on the blood, it was mentioned that one of the most marked of these is the change of colour in the passage of the blood through the lungs, from deep purple to scarlet, while the opposite change occurs in the capillaries of the system, from scarlet to purple; so that we have thus a reduction, and again a recomposition, as often as the one passes into the other.

The colouring matter of the blood is considered as a peculiar animal principle, to which the name Hæmatosin has been given. Various alkaline, acid, and saline solutions have been tried, which produce marked effects upon its colour; alkaline and acid substances darken it, while neutral saline solutions produce a florid tint. It has, therefore, been inferred that the changes which the blood undergoes in colour in the lungs and in the system respectively depend upon these causes; carbonic acid in the system darkening the hæmatosin, while its escape from the lungs enables the salts of the blood to restore the vermilion hue. This account of the colour of the blood in the venous and arterial conditions appears sufficiently simple, but unfortunately the theory is not altogether consistent with other well established facts; for example, carbonic acid does not exist as such in any greater appreciable quantity in venous than arterial blood, and the salts in the blood are not altogether neutral.

The colouring principle of the blood has also been considered to be iron, according to some, in the state of an oxide; according to others, combined with phosphoric acid. That iron exists in the blood is fully established; but in what particular state, or whether it be essential to the colour of the blood, further observation is necessary to determine.

Odour.—Newly drawn blood has a peculiar odour, which is more distinctly perceptible in the arterial than in the venous. It appears to be a peculiar volatile principle, imparting not only to different species, but also to each individual of the same species, their characteristic odour. This peculiar principle may be discharged from the blood by adding strong oil of vitriol, when it is freely liberated; so that one may know, by the odour thus evolved, the animal from which the blood had been drawn. The odour is similar to that of the perspiration belonging to each, as of man, the horse, the ox, the sheep, the pig, the rat, &c.; and so also the peculiar odour of different species of birds, of reptiles, and of fishes may be elicited. Further, it is said to be more penetrating in the male than in the female. It is well known that the different races of mankind are easily distinguishable by their perspiration. Savages can detect their friends and foes by the scent, and the dealers in hair can ascertain by the smell the nation to which the hair belongs. That each individual leaves a trace of his odour, by which his dog can distinguish his course through the streets of a city, may be observed every day, when the dog that has lost his master traces him by scent, and is thus enabled to discover him, al-

although many other persons may have passed in the same direction.

The colour and odour of the blood may be employed with advantage in the detection of crime, and in cases of criminal prosecution, in establishing the innocence or the guilt of the accused. In this view we have offered to us several points of interest, it being now sufficiently established that every new fact in science, however apparently insignificant at first, may afterwards lead to the most important results in regard to the safety, comfort, and well-being of the human race.

Consistence.—The blood cannot with propriety be considered as a fluid; for we have seen that it contains numerous globules, which in the living vessels are never aggregated together in a mass, but have been observed to possess motion among each other, and from the effects of stimulants and poisons, this motion appears to depend upon vital properties, for they are inexplicable upon known chemical and mechanical principles. The fibrin likewise would appear to be diffused through the fluid part, and not dissolved in it. In consequence of the peculiar consistency of the blood, it has an unctuous or somewhat soapy feel, and a certain degree of tenacity.

The venous blood poured into the right auricle of the heart is a very heterogeneous mixture, being composed of arterial blood, changed into venous in the capillaries of the system, of lymph absorbed from the various surfaces of the body, and of every constituent of the body, solid and fluid, taken up by the absorbents, and sooner or later poured into the red veins, and lastly, of new matter from the digestive organs; so that venous blood varies according as it is taken from different veins, not only from the materials which may have been poured into the veins, but likewise from what the arterial blood may have given off in the various secretions, and in the nourishment of the different tissues of the body. Thus blood returned from the kidneys is different, from the urine having been separated; that from the liver from the separation of the bile, and so also from the other secreting organs. The blood therefore returning from every individual organ of the body is in some degree to be held as peculiar, and different from that of every other organ. The arterial blood, on the other hand, having been formed in the lungs, and flowing to the left heart, to be propelled to the system at large, is identical, from whatever vessel it may be drawn.

Temperature and Specific Gravity.—From what has been already stated when discussing animal heat, it is unnecessary at present to treat of the temperature of the blood. It was there shewn that it differs in different animals, and in the same individual in various circumstances and conditions, that in man the ordinary temperature is about 98° of Fahrenheit, and that it is somewhat higher in the arterial than the venous blood.

Various substances possess different weights, and even the same body differs in its weight at different temperatures. In order to obtain the relative weights of liquids, it is merely necessary to procure equal bulks, and weigh them at the same temperature. For this purpose, we take a phial and place it on an accurate balance. Having got an equipoise, the phial is to be filled with distilled water, at the temperature of 60°. Supposing it to weigh 1000 grains, we have now got a standard by which we may estimate the weight of other bodies by the rule of proportion. Suppose the phial be filled with mercury, and found to hold 13,500 grains; or oil of vitriol, weighing 1845 grains; or oil of turpentine, weighing 872 grains, these will give respectively the specific gravities of water, mercury, oil of vitriol, and oil of turpentine. The blood varies in its specific gravity in different individuals, and in the same individual in different conditions, the extremes being 1022 and 1125, the medium about 1050. Arterial blood has a specific gravity somewhat less than venous; and the blood of the lower animals is generally less than that of man. Calculations have been made as to the total quantity of blood in the body at any one time; as it necessarily varies, however, according to a great variety of causes, an approximation to the truth is all that can be arrived at. The estimate of Haller may be taken as coming near the average quantity; he supposes that the blood constitutes about one-fifth of the whole weight of the body, the relative proportion being greater in youth, and less in advanced life. A body weighing one hundred and fifty pounds will therefore contain thirty pounds of blood: of these one-fifth, or six pounds, is estimated as arterial, the other twenty-four pounds being venous,—the relative quantity of arterial being less in the male and aged than in the female and young.

Chemical Constitution.—No department of chemistry is beset with so many difficulties as that which has for its object the investigation of the chemical constitution of organized matter. The chemical actions which are effected in living bodies take place between quantities so extremely minute, through instruments so complicated in their construction, and liable to influences so various, that it becomes exceedingly difficult, if not impossible, accurately to estimate the influence of each. The influence of quantity in conducting chemical processes is well known; many substances affording results, when operated upon in minute proportions, which they do not yield on a greater scale, and conversely, products are obtained by processes conducted upon large masses, possessing peculiar defects or excellencies. The distillation of spirits, the fermentation of malt liquors, and the making of bread, afford examples where the product obtained varies in quality according to the quantity operated upon.

But what is of still greater importance, the moment an animal fluid or solid is separated from the body to which it belonged, it is severed from vital influence, and immediately the reign of chemical and mechanical laws commences. The change must be as instantaneous as the electric shock, although the effects are not at once perceptible to the senses. The results of our most minute and searching examination cannot indicate the precise chemical condition of any substance, when that substance constituted a portion of a living organized structure, no more than when shewn a piece of coagulated albumen, we can tell whether it had been coagulated by heat, electricity, alcohol, or other influences which are known to produce that effect. Moreover, the condition in which the solid or fluid, as well as of the organism in general existed at the instant of separation, will to a very considerable extent determine the results; and accordingly various states of health and disease, as well as the manner of death, exert an important influence upon the blood, as shewn in its coagulation, and on the constitution of different secretions, furnishing matter of the deepest interest to the medical inquirer. Further, it is exceedingly difficult to determine whether the results obtained in operating upon organized matter, or substances produced by organized matter, be or be not products of the processes to which they have been subjected; or, in other words, in these cases there is a risk of considering as a constituent or property of a substance thus acted on, what may be merely the consequence of the action to which it had been exposed. It is to be recollected, then, that what is known of the chemical constitution of the blood, has been ascertained from the examination of, and observation upon it as a dead, and not as a living fluid. Though the condition in which it existed as a constituent of the living body influences and determines to a considerable extent the occurrences which take place after its separation, so far, indeed, that it has been considered by some that these are to be held as arising from its retaining its vitality, as, for example, the phenomenon of its coagulation, which, however, indicates nothing more than the state in which it existed while under vital influence, and is rather an indication that death has taken place than that life continues.

Generally, in about two or three minutes after emission, the blood begins to separate into a thin watery portion termed serum, and a thickish consistent clot or crassamentum. All that can be said is, that coagulation is one of the properties of the blood, as to the efficient cause of which we are ignorant. There are, indeed, not wanting many hypotheses sufficiently inconsistent with each other, which from time to time have been promulgated in order to account for it. Into the consideration of the merits of these, it would be here out of place to enter, nor would the discussion unfold much either of interest or importance. It is observed to take place more speedily in venous than arterial blood; and in that which is last drawn from an animal bled to death, and in those in a weakened, fainting, and dying condition. It is also promoted by rest, by a temperature somewhat less than that of the body, by exposure to air, and when abundant in serum. It is retarded by agitation, dilution with water, and by the addition of saline solutions, though not entirely prevented by them. It takes place when extravasated in the living body, and even within the vessels themselves, when a portion of an artery or vein is included between two ligatures. In aneurism, where a large tumour filled with blood, and having communication with an artery constitutes the disease, the blood coagulates, and after death the cavities of the heart, and the great vessels leading from it, are frequently filled with coagulated blood, forming moulds of the vessels. In these instances, the blood appears to have coagulated at the point of death, and a separation between the constituents of the clot to have been effected. These moulded pieces of clotted blood receive the name of polypi; they have given rise to idle stories of large worms being found in the heart, and the ignorant have considered them to have been the cause, not the consequence of death.

One of the most evident and important final purposes arising from the coagulation of the blood is the stoppage of hæmorrhage, for although the contraction of the coats of the blood-vessels be conducive to this end, yet the blood becoming thick and consistent, constitutes an efficient agent in arresting the bleeding in cases of wounds, by plugging up the vessels, and forming an adhesive sheath over their cut extremities; as likewise in aneurism, it occasionally happens that by the gradual accumulation of coagulated blood the tumour is filled up, and the channel of the vessel obliterated, thus effecting what is termed a spontaneous cure of an extremely dangerous disease, which generally requires a surgical operation, in some situations forming the most difficult and hazardous practised in the art.

Many circumstances modify the coagulation of blood besides those now adverted to,—such as age, sex, and temperament: in fact, the blood participates in every state of the constitution, both in health and disease, insomuch that for a long time every diseased condition was attributed to changes in the blood, and still constitutes a considerable part of the popular notions entertained respecting the nature and cause of disease. In some cases, the constituents of the clot, namely, the fibrin and red particles, separate from each other, leaving the fibrin upon the surface, forming what is called the buffy coat, as observed in different inflammations. This does not appear to arise from the coagulation taking place more slowly than usual, for even when it has occurred slowly no such appearances are presented; but seems rather to depend on a state in which the red globules and those of the fibrin are in a state of repulsion to each other, for it occasionally happens where the coagulation is unusually rapid. The clot is much firmer and consistent in some instances, as if the attraction between the particles was stronger than usual. On the other hand, the coagulum sometimes forms a soft spongy mass, a condition which is observed after violent muscular exertion; in typhus and other putrid fevers, in erysipelas, and the dreadful disease which originates from wounds got in the examination of a body, in which death has occurred in particular states. Further, in other cases the attraction between the globules seems entirely destroyed, or rather the blood is in such a condition that attraction is never established, the blood remaining permanently fluid, as when death has taken place suddenly, from a blow on the stomach, from hanging, lightning, violent mental emotion, cholera, and the worst forms of fevers. Some poisons, especially prussic acid and the venom of serpents, also produce the same effect. In these cases, the body hastens rapidly into decomposition, so that the more solid parts, as well as the blood, indicate the peculiar state of the body previous to death, and also the kind of the death itself.

The proportion of coagulum varies much in different animals, and in the same animal in different states, the average proportion being about one-third of clot. The extremes furnish equal parts of serum and clot, on the one hand, and one-fourth only of clot on the other: these extremes, however, are rare. Even in the same bleeding the proportions differ, the first cupful having a greater, and the last a less quantity of the more consistent part.

The serum is a pale straw-coloured greenish liquid of a specific gravity from 1025 to 1030. It contains a considerable quantity of albumen, so that on exposure to the temperature of 160° it is coagulated into a whitish somewhat translucent mass like the white of an egg. We have already, when treating of the proximate animal principles, had occasion to advert to the general properties of albumen, so that it is unnecessary to repeat what has been stated. If the coagulated serum be allowed to drain, particularly after being broken up and cut into small pieces, a watery fluid filters from it, termed the serosity of the blood, just as we observe the curd of milk separating into the more consistent curdy part, and the more fluid portion, the whey. Besides holding in solution the different salts of the blood, the serosity contains a peculiar animal matter which is not coagulable, and when obtained in the dry state by evaporation, is again dissolved, both by water and alcohol. At one time it was considered to be gelatin, but it is not acted upon by the characteristic tests of that substance, so that at present gelatin does not rank among the constituents of the blood.

The coagulum consists of fibrin and red globules merely in a state of mechanical mixture. The fibrin is not held in solution in living blood, but appears to be formed of colourless particles, between which in the living state there exists repulsion, but on the occurrence of death attraction is established between them, so as to produce coagulation. As has just been stated, however, this attraction is variously modified, or altogether prevented by various causes. When the mass is examined by the aid of the microscope, it presents a fibrous and cellular appearance, which has been compared to the reticulated texture of the leaves of plants. When blood is stirred with a bunch of twigs, the fibrin adheres to the twigs, and may thus be obtained separate from the albumen. If too forcibly agitated, coagulation is prevented, whether we stir the blood or agitate it in a bottle. By washing the clot with water, the colouring matter is removed, when the fibrin remains nearly colourless, presenting a fibrous structure, from which it has derived its name. The characters and properties of fibrin and the red globules having been already adverted to, they need not be further noticed in this place.

The blood contains a small quantity of oleaginous matter, which may be procured separately by agitating it with ether. In some instances it is so abundant that the serum has the appearance of whey, milk, or cream, according to the proportion of fatty matter.

The following are the results of two analyses of the blood by Le Cann.

Water	780.145	785.590
Fibrin	2.100	3.565
Colouring matter	133.000	119.626
Albumen	65.090	69.415
Fat (crystalline)	2.430	4.300
Ditto (oily)	1.310	2.270
Extractive, soluble in water and alcohol	1.790	1.920
Albumen united to soda	1.265	2.010
Chlorides of sodium and potassium; Carbonates, Phosphates, Sulphates of soda and potassa	8.370	7.304
Carbonate of lime and magnesia; Phosphate of lime, magnesia, and iron; Peroxide of iron	2.100	1.414
Loss	2.400	2.586
	1000.000	1000.000

Vital Properties.—Since the blood is endowed with many properties which cannot be explained either on mechanical or chemical principles, we are entitled to attribute them to its vitality. Its vitality has been disputed on the ground of its being a fluid; but even to admit (which is by no means necessary) that life is inconsistent with mere fluidity, we have seen that the blood cannot properly be termed a perfect fluid, as it contains numerous globules which are curiously organized, and displays properties different from those which result from physical agencies, and which cease on its being separated from the living organism, or on the supervention of death. Much depends upon the ideas attached to the terms life and vitality, and the keen discussions which have so often taken place originate in most cases from different acceptations of terms, or from the various points from which a subject may be viewed. While some have denied that the blood possesses vitality, others have gone to the opposite extreme, and considered it as the especial seat of life; and as if the writings of Moses had ever been intended for the teaching of physiology, they have appealed to such texts as the following: Genesis, ix. 4. "But the flesh, with the life thereof, which is the blood thereof, shall ye not eat." Leviticus, xvii. 11–14. "And whatsoever man there be of the house of Israel, or of the strangers that sojourn among you, that eateth any manner of blood; I will even set my face against that soul that eateth blood, and will cut him off from among his people. For the life of the flesh is in the blood; and I have given it to you upon the altar, to make an atonement for your souls: for it is the blood that maketh an atonement for the soul. Therefore I said unto the children of Israel, No soul of you shall eat blood, neither shall any stranger that sojourneth among you eat blood. And whatsoever man there be of the children of Israel, or of the strangers that sojourn among you, which hunteth and catcheth any beast or fowl that may be eaten; he shall even pour out the blood thereof, and cover it with dust. For it is the life of all flesh; the blood of it is for the life thereof: therefore I said unto the children of Israel, Ye shall eat the blood of no manner of flesh: for the life of all flesh is the blood thereof; whosoever eateth it shall be cut off." Some commentators understand these injunctions as intended to preclude such a horrid mode of using animal food as practised by the Abyssinians, who, on certain occasions, cut from the living animal flesh, and devour it, still quivering with life, and reeking in blood, at the same time taking care to avoid vital parts, that the life of the poor mangled animal may not be destroyed. Richerand thus adverts to the effects of animal diet:—"Savages, who live by hunting, and who feed on raw, bloody, and palpitating flesh, are the most ferocious of men; and in our own country, in the midst of those scenes of horror which we have witnessed, and from which we have suffered, it was observed that butchers were foremost in the massacres, and in all the acts of atrocity and barbarity. I know this fact, which was uniformly noticed, has been explained by saying, that the habit of slaying animals had familiarised them to shed human blood. But though I do not deny the existence of this moral cause, which certainly operates, I think I may add to it, as a physical cause, the daily and plentiful use of animal food, and the breathing of an air filled with emanations of the same kind, which contributes to their *embonpoint*, which is sometimes excessive." Animal food is not well adapted for a warm climate, such as Palestine is for the greater part of the year, in which the Hebrews were destined to be placed. These appear to be sufficient reasons why the great Lawgiver imposed such injunctions and restrictions on that people, prone as they were to adopt the customs and follow the practices of their neighbours, who were sunk in the most base and degrading superstitions, accompanied with the most abominable and demoralising rites and usages.

CHAPTER V.

ABSORPTION.

Purposes served by the function of Absorption—Absorption from the Skin—From Mucous Membranes—From Serous Membranes—From Cellular Tissue—From the Surfaces of the Joints—Interstitial Absorption—Its importance in carrying off the old worn-out particles, and consequent subservience to the renewal of the different parts of the Body—Special Organs of Absorption—Discovery of—Controversies respecting—Lacteals and Lymphatics—Their excessive number—Lymphatic Glands—Their Office—Case of puncture from Dissection—Endosmose and Exosmose—Venous Absorption—Causes influencing Absorption—Causes which tend to increase or diminish the risk from exposure to contagious Diseases.

ABSORPTION is that function of living organized bodies by which new matter is taken up from without and introduced into their own systems, and by which also the different constituent parts of the body itself are removed, in order to give place to others in the renewal and development of the different parts of the frame. Every organ, and every constituent particle of an organ, is subject to absorption, with the exception of the enamel of the teeth, the hair, the scarf skin, and the nails.

We may consider this function, in the first place, as it is carried on, either upon the external surface, or on surfaces having communication with it; secondly, as it occurs in shut cavities; and thirdly, where it takes place in the integral parts of the body.

First, Numerous facts prove that absorption from the skin takes place to no inconsiderable extent, though the scarf-skin, forming, as it does, a barrier between all that it covers and the external world around it, offers an impediment in a certain degree to the introduction of foreign matter. After bathing, or being exposed to a moist atmosphere subsequently to exercise, the body has been found to gain considerably in weight. Various medicinal agents also are introduced by cuticular absorption, which is much promoted when the skin is relaxed by warmth and moisture, or the function is excited by means of friction, whereby substances are insinuated between the scales of the cuticle. Exposed, as we frequently are, to noxious vapours of various kinds, and to different substances, which, if readily admitted through the skin, would be productive of most injurious consequences, the protection afforded by the scarf-skin is most important; its removal, on the other hand, is had recourse to with good effects where medicinal agents are required to be introduced into the body, in cases either where it is desirable to bring the system speedily under their action, or where we wish to avoid their direct action upon the digestive organs; and lastly, where their exposure to the digestive apparatus, and the fluids which they meet with in their course, might effect changes upon them, and thus alter their properties, and frustrate the intention with which they are exhibited. Accordingly, blisters are applied for the removal of the cuticle, when the medicine being placed upon the skin denuded of its natural defence, becomes very rapidly absorbed. Mercury, sulphur, and iodine are thus frequently introduced by the skin. Opium, and other narcotics and purgatives, such as croton oil, may obtain entrance in this way; no doubt these also affect the system from the impression they produce upon the extremities of the nerves distributed on the surface of the body. From the extensive surface of the air-passages, absorption is very readily effected on exposure to the vapour of turpentine: the presence of that substance will in a few minutes be indicated in the urine. The breathing of an atmosphere loaded with alcoholic spirits soon produces intoxication; and a person entering a snuff-manufactory, even although in the habit of using tobacco, is so powerfully impressed that in a few seconds he experiences great prostration of strength, and sickness and vomiting are apt to supervene. The poisonous miasmata emanating from those labouring under contagious diseases are most readily received by the breath; indeed, it is chiefly by cuticular and pulmonic absorption that they are propagated. The noxious exhalations from stagnant marshes and other unhealthy situations are introduced in the same manner. Medicated vapours are inhaled frequently with greater advantage than can be derived from the use of these agents in any other way, particularly in diseases of the lungs, where they operate not only by their direct effect upon the extremities of the nerves, but also in consequence of their being immediately taken up by the vessels of the lungs.

We have already had occasion to advert to absorption from the alimentary canal. Throughout its whole extent this function is carried on with more or less rapidity, according to a variety of circumstances; and, as we have seen, it is from this surface that new matter is derived, to compensate for the losses to which the system is constantly exposed. Medicines are much more commonly exhibited by the mouth than in any other way, whether they produce their effects in consequence of their impression upon the nerves distributed on these parts, or are taken up and carried into the general circulating mass, and subsequently induce their specific effects upon distant organs, on which their action is expended. The facility and the rapidity with which substances are carried off from the alimentary canal is surprising. Various colouring and odorous principles, such as rhubarb and garlic, are in a very few minutes detected in the breath or in the urine. The extent of this surface for absorption is not limited to the alimentary canal, but is extended to the internal surface of all the excretory ducts which terminate in it. The salivary, biliary, and pancreatic ducts must be included: where these are obstructed, the secretions which they convey are again taken up and carried into the system. Thus in jaundice the whole surface of the body is rendered yellow, from the bile being conveyed into the general circulation. In the same manner does absorption occur from the other surfaces continuous with the external integuments, and having communication with them, as the lining membranes of the nose, eyes, ears, &c.

Secondly, There are several shut sacs in the body termed serous membranes; others belong to the joints, and are named synovial membranes: and analogous to these in several repects is the cellular membrane. A few observations respecting each of these may be here advantageously introduced. The serous membranes are thin, transparent, or semi-transparent webs, extended over the contents of the different cavities, and reflected upon the walls of these cavities so as to form shut sacs. They have been rudely compared to a double night-cap, the layer immediately in contact with the head being analogous to the portion of serous membrane immediately investing the viscera, while the external layer is likened to the part reflected upon the walls of the cavity, the space between them being the unadherent, free, secreting, and absorbing surface. One of these belongs to the brain and spinal cord; from its thinness and delicacy it has been compared to the spider's web, and therefore named the arachnoid membrane. It covers the different surfaces within the skull and spinal canal. There constantly exhales from it a thin vapour, which preserves the different parts moist, enabling them to glide easily upon one another in the slight movements which take place between them. In the chest there are three of these membranes: one investing the heart, and from that circumstance named the pericardium; the others termed pleuræ. The two pleuræ adhere to the external surface of the lungs, and are reflected upon the inner side of the walls of the chest. They divide the thorax into two lateral cavities. In these bags a vapour exhales to preserve the surfaces moist and slippery. The most extensive of all the serous membranes is situated in the abdomen; it not only furnishes a covering to the contents and walls of the belly, but by its numerous and extensive folds its surface is still farther extended, so as to form one of the most expanded in the body. One of the most remarkable of these folds proceeds from the inferior convexity of the stomach, over the transverse portion of the colon, below which it is doubled upon itself. This is known under the name of omentum or apron. It affords occasionally lodgement for a considerable quantity of fat, and extends over the front of the bowels between them and the parietes. Besides increasing the surface for absorption and secretion, it serves the purpose of a roller in machinery, being a moveable body interposed between two other moveable bodies, by which motion is facilitated and friction diminished; but its vast superiority over similar mechanical contrivances of art is displayed, not only in its delicacy and pliability, but in furnishing a lubricating fluid in a quantity commensurate with the expenditure. There is a membrane within the eye secreting the aqueous humour, and another in the internal ear, which are similar to the more extensive serous membranes of the cavities.

The fluid exhaled from these membranes is analogous to the serum of the blood, but it differs somewhat as derived from each. That of the arachnoid contains very little albumen, probably from the extreme minuteness of the vessels which discharge it; for even after being long subjected to inflammation, no red vessels can be observed upon that membrane, the loss of transparency, and a certain degree of thickness, being the only change it appears to have undergone, while the thicker and more dense pericardium, pleura, and peritoneum discharge a fluid more closely resembling the serum. When affected with inflammation, a large quantity of albumen is secreted, which occasionally coagulates so as to glue the different parts to each other; sometimes the serum is even bloody, and in other cases its character is changed into a pus-like fluid. In the healthy state an accurate balance is preserved between exhalation and absorption in these bags; but if this balance be subverted, either from the increase of secretion, or from the diminution and obstruction of absorption, then an accumulation takes place constituting a dropsy. Such accumulation cannot take place within the skull and spinal canal to any considerable extent, unless they yield to the internal pressure, as they occasionally do in infancy and childhood before the bones are firmly united. Thus, *water in the head* may collect to a very great extent. In one instance where the patient laboured under the disease for twenty-one years, we took from the skull ten pints and a quarter of limpid fluid; and even larger quantities have been observed. Similar collections take place in one or other or both of the two pleuræ, which are accompanied with considerable embarrassment of the function of respiration, and may prove fatal from the mechanical pressure on the lungs preventing them from duly performing their office. So likewise dropsy occurs in the pericardium when the movements of the heart are impeded and disturbed. From the construction of the walls of the chest dropsies within that cavity are necessarily attended with a comparatively small quantity of water; whereas in the abdomen, surrounded with walls which admit of great distension, the accumulations which sometimes take place are amazing, several gallons being in some instances drawn off by the surgeon at one tapping, and that repeatedly from the same person. In all these cases the water is merely to be considered as the consequence of disease, not the disease itself, though it may by mechanical pressure be productive of serious results.

Now when we reflect that in all these cavities, during the whole course of our existence, watery fluid is constantly poured out, and therefore requires to be as constantly removed, we perceive how accurately the balance between the two functions must be preserved. The slightest deviation from the natural state must be followed by consequences incompatible with the health, and even the life of the individual. But so admirably are these functions adjusted that accumulations of serum are of rare occurrence, when the number of causes which tend to produce them are taken into account, or they arise from such slight and temporary causes that the parts are easily and speedily again rendered conformable to their wonted healthy action. The rapidity with which these collections occasionally disappear sufficiently indicates how very actively absorption may take place in these serous membranes. Besides, experiments have been performed on living animals, in which large quantities of fluids having been thrown into these sacs, have been found to be carried off in the course of an hour or two.

The joints are furnished with membranes which cover the articular surfaces, and pour out the synovial fluid. In their structure and general appearance they very much resemble the serous membranes; they are, however, more dense and less elastic, and the fluid which they secrete differs somewhat from that of the serous sacs, being viscid and tenacious, from the presence of a principle resembling mucilage. Besides the capsules of the joints, there are in various parts of the body little synovial pouches like air cushions, placed between muscles and the asperities of bones, and likewise interposed between muscles themselves, where they would otherwise be liable to pressure on each other: they are like the Macintosh air cushions, but of a more excellent construction, for they accurately adapt themselves to the varying forms and positions of the different parts, and the quantity and quality of synovia furnished by these capsules and pouches correspond to the extent and continuance of the motion to which they are exposed. When they have been excited for some time in an inordinate degree, as from a long journey, after a little rest the secretion becomes deficient, and the joints and limbs stiff, but on being roused again into action by exercise, they pour out a due quantity, and the stiffness disappears. Absorption from these surfaces must be commensurate with secretion, otherwise an accumulation takes place, as sometimes happens, forming dropsy of the joints, which may be discussed by promoting absorption by means of friction, liniments, blisters, &c.

The cellular membrane is the most universally diffused of all the tissues of the body. It forms a constituent of almost every organ, and serves to separate the different parts from each other, and to constitute the general bond of connexion between them. It is formed of an infinite number of small thin membranous plates, forming cells of an irregular shape, and strengthened by filaments crossing in different directions. These cells communicate with each other. They vary in the size and strength of their walls in different situations. From the surface of the plates forming the cells a serosity is exhaled, which preserves them moist and lubricated. This does not appear to differ from that furnished by the serous sacs. Dispersed through the cellular tissue of several parts of the body, there are other cells, in which fat accumulates, distinct apparently from those which secrete serum, and which do not communicate with each other. The fat cells vary much in size and shape in different parts of the body. They are large, and of an irregular shape in the orbit of the eye, and around the kidneys, small and of a spherical form in the scalp. Some parts always contain fat, as the orbits, the soles of the feet, and the extremities of the fingers and toes; others generally have more or less, as immediately under the skin, around the heart, in the folds of the peritoneum, and around the kidneys; while with the functions of others its presence is incompatible, as the eyelids, the brain, &c.

The quantity of fat in the body, even in a perfect state of health, varies prodigiously, from scarcely an ounce or two in some living skeletons, as they are termed, to the monstrous accumulations of several hundred pounds. Both the serosity of the cellular membrane and the fat may be deposited in greater quantity by the secernants than the absorbents may be able to remove. In some cases of great laxity and debility, the serosity accumulates in the depending parts of the body, and thus the feet and ancles may swell during the day, and again the swelling entirely disappear, after the horizontal posture in bed, in the morning, the fluid having been carried off during the night by absorption. From the obstruction offered by the enlarged womb in the latter stages of pregnancy to the return of fluids, the lower limbs frequently swell, especially towards evening. In diseased states, the quantity of serum collected in the cellular membrane is frequently very great in this form of dropsy; and when a favourable change is effected, it is as rapidly removed by the absorbents.

Lastly, The fluids are not the only parts of the organism of living beings which are subject to constant removal and replacement, but every tissue, and every particle of which that tissue is composed, sooner or later become unfit for the situation in which they are placed, and requires, therefore, to be removed, in order to be replaced by another better suited to the purpose. The animal body does not grow by additions, like a crystal, nor by simple dilatation and distension of the individual parts, which neither their texture nor organization admit of; but every old particle is removed, and a fresh one deposited in its stead; or if growth and enlargement be going on, there is not only depositation in proportion to the expenditure, but an increase in the number of the materials of which the organ is composed. The bones of the child are very different in density, form, and texture from those of the adult, and so it is also with the other solid parts of the body. We perceive, likewise, tumours are frequently developed from diseased action, and again removed by absorption. In short, from the first dawn of our existence till life is closed, there is a perpetual and unceasing contention between the vessels which deposit new matter, and those which remove the old, the result of the actions of both constituting nutrition.

At the commencement of life, the preponderance is in favour of the depositing or secreting vessels. From day to day the framework is enlarged, and the different organs in succession gradually unfolded, till they reach their full development. For a time the two functions are equipoised, and the body appears to suffer little or no perceptible change; but as age advances, many of the secreting vessels are obliterated; the organs shrink one after another, at last become unfit for carrying on the operations of the machinery, and the scene closes.

When the balance is subverted between the two functions, either accumulation or diminution must be the result, producing growth or decrease, according to the activity of the one or of the other. The term *interstitial* absorption is applied to the function, as thus exercised upon each individual tissue of the body.

The absorbents appear to have less vitality and irritability, and to participate less in the various conditions of the system in health and disease, than the secreting vessels; and therefore when the action of the latter is diminished or suspended, that of the former continues, consequently its effects become more perceptible, and it seems to be increased; whereas it may not in such cases have undergone any augmentation, but even suffered decrease, though not to the same extent with its antagonist. In fevers and other acute diseases, where the digestive function is stopped, and the expenditure of materials still goes on, emaciation is the consequence; and the same occurs from starvation and other causes of inanition, shewing that the absorbents continue to perform their office. When a morbid growth has taken place, the object of the medical practitioner is to endeavour to diminish the action of the vessels which nourish it, and thereby produce a preponderance in favour of absorption; or he determines the force of the circulation to some other part, as the kidneys or skin, so as to procure copious evacuations.

When the depositing vessels are interrupted, as from pressure of a tumour or other causes, absorption will still go on, so as to remove the parts thus deprived of their due quantity of nourishment. If the pressure be upon a bone, the earthy part is first removed; or if on a muscle, the fibrin is that which is first carried off, leaving the cartilage of the one and the cellular substance of both to be the last for removal. Now, this apparent selection of earthy matter and fibrin arises, not from any preference the absorbents have for either, or from their being more easily absorbed, but from there being no fresh depositation of them to compensate for what is removed by absorption.

When blood or any other fluid is extravasated, as from blows or bruises, these substances being placed out of the sphere of vitality, and in every respect become dead foreign matter, the absorbents nevertheless continue to act upon them, and in time carry them off altogether. In the same way, when a bone or any part has been deprived of life, the absorbents operate upon them so as to cause their removal, while the secernants may at the same time be engaged in the production of new ones in their stead. From these circumstances the absorbents have been termed the scavengers of the body, as they are constantly engaged in removing old worn-out and superfluous matter from every part of the system.

Absorbent System.—The term absorbent system is here meant to be confined to those organs which are chiefly engaged in taking up and conveying from the different parts of the body the various materials of which it is composed, although they do not exclusively perform this office. The absorbents have been described by some as a subordinate set of veins, differing from the red veins, in transmitting colourless instead of red blood, but terminating in the veins before they reach the heart. In their structure, however, as well as in their office, there exist characters which sufficiently entitle them to rank as separate organs.

The ancients and earlier modern anatomists appear occasionally to have noticed these vessels, but they had no correct notion of their use. Aselli, an Italian, seems to have been the first who observed the lacteals, which he did on opening a living dog in the year 1622, and ascertained their office, but believed that they conveyed their contents to the liver. Pecquet, in 1657, discovered the absorbent trunk in which they terminate, now known under the name of the thoracic duct. Much about the same time similar vessels were noticed to arise from different parts of the body, containing a colourless fluid or lymph, hence named the lymphatic absorbents, which led to an acrimonious dispute as to the priority of discovery between Jolliffe, an Englishman, Rudbeck, a Swede, and Bartholin, a Dane, into the merits of which it is unnecessary for us to enter. During the last century, by the labours of the Hunters, Hewson, Cruikshank, Mascagni, and the second Monro, they were observed proceeding from every part of the body, with perhaps the exception of the brain and spinal marrow, though Mascagni has figured some small lymphatics from the brain, which he succeeded in detecting and injecting. Their existence has been disputed in these parts, as well as in the interior of the eye, for no other reason than that they have not been seen by those who have looked for them. Mascagni devoted great attention to the investigation of the absorbent system, and his experience enabled him to inject these vessels with greater success than any other person. Besides the general difficulties in the way of preserving such preparations, he had to contend against the warmth of the climate of Italy; and therefore contented himself, after a successful preparation of the parts, with an accurate representation of them, and there appears to be no reason to doubt his integrity.

It requires no small experience and dexterity to trace and properly display the minute parts of organized structures, and he who is deficient in the necessary tact and experience has no right to dispute the existence of arrangements which he finds himself incapable of unfolding. No one dreamt of the stars, and systems of stars, which the telescope has declared in the hands of a Kepler, a Newton, and a Herschel; nor imagined the structures which have been unfolded by a Hooke, a Lewenhoek, and a Bauer, by means of the microscope. There can be no doubt that the function of absorption is carried on in these parts, as well as in the rest of the body. The fact that the lymphatic glands of the neck have been observed to be affected in diseases of the brain, tends to prove the existence of absorbents in that organ. Many as have been and still are the disputes as to the merits due to different individuals, with respect to discoveries made in anatomy and physiology, and as to the respective credit belonging to each one who may have contributed to the establishment of a popular and generally received doctrine, the absorbent system has furnished an arena in which controversies with regard to these points have been carried on with greater keenness and acrimony than in any other department of these sciences.

The absorbents have a greater resemblance to veins in their structure and functions than to arteries. They consist of two layers or coats: the external is cellular, the internal thinner, and similar to the lining membrane of the other blood-vessels, being smooth and slippery, and bedewed with an exhalation from the extreme arteries supplying those coats. The extreme thinness and transparency of their coats, along with the colourless nature of the fluids which they generally convey, was the reason of their existence being so long unknown, and the difficulty which exists in tracing them. Notwithstanding the thinness of their coats, they possess considerable strength, so as to support a higher column of mercury than arteries or veins of the same diameter. The internal coat is folded, so as to form little semilunar valves, generally in pairs, which, like the corresponding valves of the veins, prevent the retrograde movement of their contents, and force it to pursue the course towards the heart. These valves are exceedingly numerous, so that when injected they present the appearance of a string of beads.

We noticed, when treating of the veins, in the chapter on circulation, that it is only in the veins of those parts of the body which are subject to voluntary motion, that valves exist, and that there are no valves in the veins of the viscera. The absorbents are different in this respect, being furnished with valves equally in every part, whether superficial or deep-seated, whether subjected to the will or beyond its control. These valves must therefore be more essential to the action of the absorbents than that of the veins. The veins being principally engaged in returning the blood from the various organs of the body, and the blood being impelled along them from the force communicated from the arteries behind, it flows through these vessels, even independently of the action of the veins themselves, while the fluids in the absorbents are not influenced by any such impelling power. From absorbents possessing less irritability and vital contractility than other vessels, and their contents being transmitted chiefly by their mechanical elasticity, possibly aided however by a proper vital contractile power, there arises the necessity for mechanical contrivance to insure the flow in the proper direction of the fluids they transmit; hence the number and universal distribution of the valves. These valves offer a great impediment to the successful injection of the absorbents, since it is necessary to introduce the instruments into their minute further extremities, whereby it becomes exceedingly difficult to trace them with any degree of success.

The absorbents are much more numerous than either of the other two sets of blood-vessels. Though they do not form any considerable trunks, they establish frequent and reiterated unions with each other, so that if one is obstructed, the contents can easily pass along another channel. Like the veins in the limbs and external parts, they are divided into two sets, the superficial and deep-seated, probably for the same reason which we had occasion to suggest was the purpose served by a similar arrangement of veins, and they generally pursue the course of the venous trunks, just because that is either the most direct or the most secure.

Although the thoracic duct be often described as the common trunk of the absorbent system, from its being larger and more regular than any of the other absorbents, it does not appear to deserve that distinction, for many of the absorbents terminate in the veins, especially in the right subclavian, without joining it, and several terminate in veins at a considerably greater distance from the heart. Indeed, the absorbents from the lower limbs, abdomen, and chest, could have in no other direction pursued so safe a course as that along the vertebral column, just as we perceive the veins from the upper part of the walls of the abdomen and chest unite in the formation of the vena azygos. The final termination, then, of all the absorbents, is in the veins, generally the two large veins under the collar bones, named the subclavians. Although the absorbents do not unite so as to form vessels of any considerable size, they are exceedingly numerous, and constitute bundles of net-work in almost every part, especially on the inner side of the arms, legs, and thighs, on each side of the neck, and along the vertebral column. Their valves preventing successful injection, they require great care and expertness in order to trace them. On one occasion, in the class-room of the distinguished teacher of anatomy in Edinburgh, the late Dr

Barclay, the thoracic duct, as usual, was filled with quicksilver, for the purpose of demonstration to the class, when the injection flowed from the duct to the absorbents of the lungs, diaphragm, and walls of the chest, and that too so exceedingly minutely and generally, that they formed a most splendid appearance of lace-work of silver tissue, leaving not a space on these surfaces into which the point of the smallest needle could be inserted without wounding several of the vessels of which it was composed. This appearance was altogether unprecedented, and left an impression on the minds of those who had the good fortune to witness it, which can never be obliterated, and which conveyed an idea of the excessive number and universal distribution of these vessels which no description can convey. In this instance, either the valves did not exist, or they acted imperfectly. No anticipation having been entertained of such an occurrence, the body had been dissected in such a manner that the quicksilver so rapidly made its escape that in less than an hour scarcely a trace was left of this interesting appearance, except on the memory of those who saw it.

A circumstance which distinguishes the absorbents in an especial manner, is their passing through certain bodies termed glands in their course. These are fleshy bodies of a lenticular or globular form, abundantly supplied with blood, varying in size from that of a filbert to the smallest grain of sand; so minute are several of them that they are invisible, excepting when they become enlarged by diseased action, without which their existence could not be suspected. They are numerous, and collected into clusters in some situations, as along the sides of the neck, in the arm-pits, groins, at the bifurcation of the windpipe, and in the abdomen, between the layers of the mesentery. When an absorbent approaches one of these bodies, it begins to divide into numerous twigs which enter the gland, in the substance of which the different branches of these vessels freely communicate with each other, and also establish connections with veins; so that injections pass from the one into the other. The number and size of the arteries, also, are much greater than is merely requisite for their nourishment; hence the probability that the arterial blood is subservient to the function carried on in these organs. The absorbents passing out of the glands again unite into larger branches, and in the same way they may enter and pass out of these bodies several times before they ultimately pour their contents into the veins. The annexed figure, formerly introduced, shewing the passage of the lacteals through the glands of the mesentery, will illustrate these points.

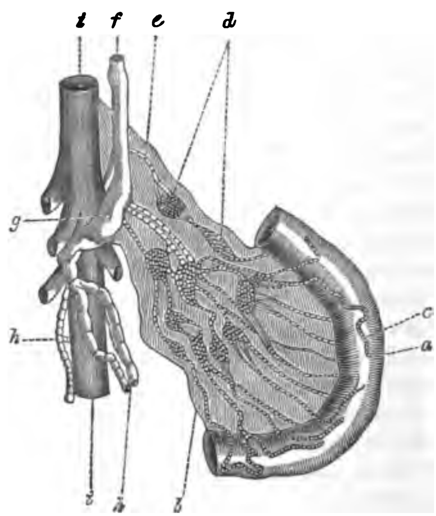

FIG. 15.

We have already had occasion, when treating of the passage of chyle, to state, that a change is effected upon that fluid during its passage through these bodies, whereby it becomes more elaborated, and approaches more closely to the constitution of blood. It is not unlikely that a mutual interchange is effected between the three fluids—namely, those of the artery, the vein, and the absorbents. The fluid conveyed from every part of the body ought not to be considered as merely old worn-out and useless matter, otherwise why is it again introduced into the general circulating mass; if only for the purpose of its subsequent discharge, we should have expected a more direct course to the organ by which it should be evacuated. This not being the case, it is fair to infer that it serves some useful purpose in the animal economy. It may be stated, that the blood in the veins, the lymph in the lymphatics, and a great part of the chyle in the lacteals being derived from arterial blood, so do these again unite to be reformed into arterial blood in the lungs, and thus a circle of decomposition and recomposition of the one and of the other, is continually taking place in the lungs, and in the system at large,—a change being perceptible in the chyle, which we are more easily enabled to detect, from its colour and constitution, as well as from its quantity, when proper advantage is taken after a meal for procuring it. An analogous change may be inferred to be effected on the lymph in its passage through the lymphatic glands. The materials which the absorbents take up and convey being as various as the tissues of which the body is composed, the heterogeneous matters, in filtering through these glands, and on being subjected to their action, are both thoroughly mechanically intermixed, while they are converted into a fluid of a more homogeneous nature, and qualities which they might possess previous to entering them, may be so modified and altered as to adapt them to their introduction into the general circulation, whereas, had they been introduced without undergoing such change, their presence might be highly prejudicial. It is well established that many substances act with much greater intensity when immediately injected into the blood, than when they are conveyed into the system through the circuitous and intricate channels of absorption. The deadly poison of the rattlesnake, or of the cobra-de-capello, may be swallowed with impunity, while the introduction of the most minute quantity by a wound inevitably causes death, in some instances in a few minutes. In the former case the poison is digested, and its composition and properties altered and destroyed: in the latter it acts on the body in its state of unchanged integrity.

But the glands, besides acting as vital agents in altering and elaborating the fluids transmitted through them, offer a mechanical obstruction to the too rapid introduction of matter into the general system. It is well known that the animal frame will bear the introduction of foreign matter with impunity, when it enters in detail, which it is incapable of resisting when rapidly applied in the mass; the system having time either to accommodate itself to the circumstances, or expel the injurious matter through the excretory organs in the former case, while in the latter there is neither time to guard against its influence, or for its expulsion. We can often trace the course of an absorbent which has conveyed acrid or poisonous matter, by its becoming inflamed; red streaks being observed from the point where the substance was absorbed, along the course of the absorbents, up to the next lymphatic gland, in which its progress is arrested. The gland becoming irritated from the presence of the poison, inflames and swells, and frequently suppurates, establishing a new secretion. In many cases, no trace of the poison can be detected till it reaches the gland, which becomes hard, painful, and swollen. There can be no doubt that this arrestment of the poison in its progress tends to the preservation of the system, so much so, that I believe that I owe the preservation of my own life to this conservative arrangement of the absorbing system, as the following account will show, and which is here introduced by way of illustration.

Eight years ago, a patient of mine died under circumstances which rendered me suspicious that the fluids were in such a condition as was likely to be productive of the worst effects, if introduced into a healthy person, either by puncture, scratch, or other kind of wounds inducing that peculiar and often fatal disease characterized among other symptoms by a diffuse inflammation of the cellular membrane. My attention having been particularly directed to the nature and treatment of this affection, from eminent professional men having been cut off by it, from having witnessed the agonies and death of some of my own friends and fellow-students, and from my occupations at the time, I chose this subject for my probationary essay submitted to the Royal College of Surgeons of Edinburgh, when I joined that body.

I was not in the least deterred from requesting the examination of the body of my patient, there having been symptoms present which made investigation desirable. From the suspicions excited in my mind with respect to the state of the body, I would not permit my pupils who accompanied me in any respect to interfere with the operation, as I considered that my experience rendered me more expert in the use of the instruments. Having employed every precaution, the operation was conducted in the usual way, and I left the house to attend to my duties, without the slightest suspicion or apprehension, having similarly examined some hundred bodies before. After noting down the appearances observed, the subject was entirely dismissed from my mind. I was in as excellent a state of health as I had ever been in my life, and enjoyed perfect elasticity both of mind and body.

Next morning at breakfast I felt somewhat chilly, and did not enjoy my meal with my usual appetite. After breakfast I called upon a patient at some distance, when I suddenly became affected with great prostration of strength, sickness, and shiverings, and for the first time became alarmed from a stiffness and pain in the armpit. On narrowly inspecting my hand I found that a small piece of scarf skin had been abraded from the back of the ring finger of the right hand, which was a little red, but without pain or swelling, and not the slightest trace of an inflamed absorbent could be noticed.

In the evening the nature and character of the disease were fully established. From having made the affection the subject of careful study and observation, and having had some experience of its treatment, I did not feel the slightest apprehension as to the issue.

I passed the night in great pain and distress, and on the following day the arm was swelled from the wrist upwards; the swelling also extended to the chest as far as the breast bone in front to the spine posteriorly on the right side, and also up the neck to the ear. The late distinguished Professor Duncan junior and other professional friends saw me. The pain was most excruciating, rendering motion impossible; but the mind was unaffected, either with apprehension or otherwise, except with the fear that delirium might supervene, and render me unfit to conduct the treatment, or judge of the suggestions of my friends.

The night was again passed without sleep, and the symptoms became more and more aggravated. About noon of the third day I experienced for the first time a perfect indifference to life. Though suffering great agony, there was no desire for death, but as I repeat, a perfect indifference as to the result. Nor was I at the time conscious, nor am I yet convinced, that my mind was otherwise unhinged.

Besides leeching, the principal reliance was placed on the blue pill, which from the first time the disease unequivocally displayed itself was regularly taken every two hours, in the dose of two of the ordinary pills, its action on the bowels being restrained by the use of kino.

After the twenty-sixth dose indications of the medicine having made its impression presented themselves. About three o'clock in the morning of the fourth day, for the first time, I fell asleep, and awakened at half-past seven completely drenched in most profuse perspiration. At the same time the love of life was completely restored, and although I was fully aware that the crisis had passed favourably, for the first time I became exceedingly anxious, as, in the state of helpless debility and exhaustion to which I was reduced, I well knew that the slightest relapse would most probably have a fatal termination. Indeed it is impossible for me to describe the very great and remarkable mental change which a few hours had brought about. In the evening an opening was made in the armpit, from which about a pint of pus was discharged, and from this time I slowly and progressively recovered. It was not, however, for more than twelve months that the discharge entirely ceased, during which I conceive my constitution underwent a greater change than in seven years of my life.

The absorbent system, then, consists of vessels and glands. The vessels are extremely numerous, arising from every part of the body, never collected into trunks of any considerable size, having their transparent but dense and tough coats freely communicating with each other, abundantly furnished with valves, and finally terminating in the veins. The glands are firm fleshy bodies copiously supplied with blood, varying in size, frequently collected into clusters, through which the absorbents pass once or several times in their course to the centre of circulation, in which they are variously coiled and interlaced with each other, and with the arteries and veins, establishing frequent communications with each other, and with the veins, and where their contents are for sometime arrested, and subjected to a certain degree of alteration.

This system is usually divided into the lacteal and lymphatic absorbents, not from any difference which can be observed either in their structure or the function which they perform. This distinction between lacteals and lymphatics is to be rejected, as it is apt to mislead and produce an erroneous notion with respect to them, since the lymphatics do not always convey a colourless fluid or lymph, nor do the lacteals always transmit chyle,—the former frequently containing fluid of a reddish tint, and the latter occasionally transparent lymph.

Mode of Action.—The extremities of the absorbents are frequently described as important agents in the function of absorption, under the name of *mouths* of the lacteals and lymphatics, and the action of these mouths described in such a manner as would lead to the supposition that they are easily observed, and their office, and mode in which they perform it, fully ascertained. This is, however, by no means the case, the greater part of what has been written on this subject being more a matter of conjecture than observation; and when the extreme minuteness of these extremities is considered, when we reflect that Leuwenhoek estimates that a single grain of sand could cover some millions of them, we will be less disposed to place implicit reliance upon detailed descriptions respecting them. The sum of our knowledge with regard to this point is, that we know that fluids from the surfaces, and the materials from every part of the body, do enter the absorbents; but whether that entrance be effected in consequence of a mechanical structure such as is observed in the capillary tubes, and therefore named capillary attraction, or by a proper vital action analogous to the vital contractile power with which the extremities of the arteries are especially endowed, cannot be determined, though it is probable that both are to a certain degree instrumental in the performance of the duty.

It has been ascertained that substances readily permeate organic tissues, without any special reference to the texture of these tissues, but rather according to the laws of attraction and repulsion, which may operate on the fluids which these tissues separate from each other.

FIG. 16.

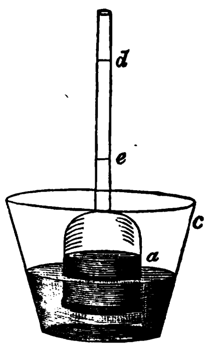

FIG. 17.

If we take an instrument such as represented in Fig. 16, resembling a bottomless phial, *a*, with a long stem like the tube of a thermometer, *b*, and cover its lower orifice with a piece of animal membrane, as in Fig. 17, at *b*, and fill the phial half full with syrup, mucilage, or milk, and then place it in the cup *c*, half filled with water, we shall find that the water passes through the membrane into the syrup, and that the fluid will ascend to any height in the stem, as to *d*. On reversing the experiment, by filling the phial and its tube quite full of water, and putting it in the cup, having such fluids as mentioned placed in it, we shall now find that the water passes out of the phial into the cup to join the syrup or mucilage, and a descent will take place in the stem to any extent, as to *e*. If a bladder be filled with pure hydrogen gas and exposed to the air, in a short time the bladder will be found to contain atmospheric air alone; in this instance the hydrogen has passed out of the bladder, and the atmospheric air entered into it, and both changes have been effected simultaneously.

The roots of plants terminate in exceedingly minute radicles, frequently, however, bulging out into small bulbous bodies, which have been termed spongiols. These extremities are composed of a very delicate tissue without any cuticular covering, and very actively perform the office of absorption by a kind of imbibition, or endosmose as it has been called. They also give off fluids to the soil in which they are planted, thereby imparting peculiar properties to it by exudation or exosmose.

When it is recollected that the internal surface of the absorbents, however minute, is a secreting surface from which an exhalation is poured out from the arteries distributed upon it, we can readily comprehend how these vessels may be filled with fluids from the arterial blood, and endowed with peculiar properties whereby they may exert attraction for substances exterior to their coats; and when we know, as we do, that fluids easily penetrate much thicker and even more dense membranes and other tissues than the exceedingly thin and delicate coats of the absorbents, we can have no difficulty in understanding the manner in which they may pass into the absorbents. Further, since gases, fluids, and even solids exert different degrees of attraction and repulsion towards each other, and since we observe that materials are taken up from the alimentary canal, for example, by some vessels, and rejected by others, it is quite possible to explain these apparent selections and rejections on the above principles without having recourse to any peculiar vital property with which the absorbents or their minute extremities or mouths may be endowed.

At the same time, there is every reason to believe that the absorbents are not merely passive tubes: we have had occasion, when treating of the arteries, to observe that their minute capillary extremities possess considerable irritability, and exert considerable influence on the circulation, both in states of health and disease. That they derive their nervous energy from a peculiar class of nerves is sufficiently established: that the veins participate in these properties and nervous influence, though in a minor degree, is also evident. If irritability and vital action be conceded to the capillaries of the arteries and veins, there appears to be no good reason for withholding them from the absorbents, although, from the greater density of their coats, it is probable that they possess a much inferior degree of irritability than even the veins, and are less under the influence of those causes which tend to interfere especially with the action of arteries: hence circumstances which interrupt or totally destroy depositation or secretion, as in the death of any particular organ, as a bone or a morbid growth, produce little effect on the absorbents, which continue to carry on their action till the part affected is entirely removed.

That the absorbents exert a certain degree of pressure, is shewn by their expelling their contents with a considerable force when punctured; but whether this depends upon their being furnished with a muscular contractile power, or upon mere mechanical elasticity, is also a question which it is difficult to determine. The most careful and close inspection has failed in detecting more than an external cellular coat, and an internal serous one. The middle, corresponding with the muscular coat of the arteries, is universally omitted by anatomists in their descriptions; but though, from the minuteness of these vessels, we may fail to observe muscular fibres, even when aided by the microscope, its non-existence is inferred entirely upon negative grounds, and, reasoning from analogy, a muscular coat should be admitted in the absorbents. At all events, the fluids, which are poured into them by the arteries, being under the influence of the agencies to which secreting vessels are subjected, and as the nature of the fluids contained in them will regulate the attraction and repulsion between them and substances exterior to their coats, even on these grounds the introduction of materials into the absorbents cannot altogether be held as arising from mere mechanical laws.

The pressure which the absorbents exert upon their contents will impel them towards the heart, for the number of valves with which they are furnished will permit the fluids they convey to pursue no other course. Therefore, admitting that they have no muscular coat, their elasticity will be sufficient to explain the motion of their contents without the aid of capillary attraction. The movements in surrounding parts, such as muscular contractions, will also operate to a certain extent, and even the motions of the vessels which they accompany will in some measure contribute to the same effect; the differences also produced on the atmospheric pressure within the chest, and on the surface of the body, already alluded to, as an agent subservient to the circulation of the blood, will exert its influence in promoting the current in the absorbents, which, as just now observed, can take place only in one direction.

Venous Absorption.—Previous to the discovery of the lymphatics, absorption, as far as it was understood, was supposed to be carried on entirely by veins. As the existence, structure, and use of the lacteals and lymphatics became gradually unfolded, the opinion that these vessels exclusively executed the office of absorption became generally and almost universally entertained. Farther observation and experiment have shewn that this duty is shared by the veins, and that also to no inconsiderable extent.

Several lacteals and lymphatics are observed to pour their contents into veins in the immediate neighbourhood of the seat of their origin, and such connexions more especially occur in the lymphatic glands; still, independently of the communication thus established between these vessels, the veins have been shewn to perform the function of absorption by their own proper action. When we considered the removal of substances from the alimentary canal, we had occasion to state that the lacteals are the chief instruments by which the chyle is carried off; but that water, chemical substances, various colouring and odorous principles, found entrance by the branches of the vena portæ, whereby they were carried through the liver before they were introduced into the general mass of blood.

In the same way, substances which can be identified by their odour, colour, or chemical properties, have been injected in the intestinal canal into the serous sacs, as into the cavity of the peritoneum, into the windpipe, and into the subcutaneous membrane. In all of these instances they were found either exclusively, or more abundantly in the veins than absorbents, and in several cases they could be detected in the former before any trace of them could bo ascertained in the latter.

Indeed there is nothing with regard to the functions which the veins exercise incompatible with absorption, the most important and well-marked difference between the two sets of vessels consisting in the existence of the fleshy bodies termed glands in the course of the lacteals and lymphatics, the office of which appears to be to produce a certain degree of alteration and assimilation of the matters they transmit previous to their introduction into the general system. In the distribution and filtration of the blood of the vena portæ through the liver, a vein which, arising as it does from the alimentary canal, and therefore having presented to its radicles new and foreign matter, an arrangement exists whereby similar effects can be brought about; and still further, in the secretion of the bile from the blood of the vein in question, an opportunity is afforded for the removal of substances, the introduction of which into the general circulation might prove prejudicial.

Causes influencing Absorption.—Several circumstances tend either to accelerate or retard the function of absorption, and exert an important influence in many conditions of health and disease. It has been shewn that the states of repletion and inanition especially have great influence in respect to the rapidity or slowness with which materials are taken up, whether foreign to the body or forming part of its constituents.

Experiments performed by M. Magendie, in illustration of this, may be here introduced.

" In a public lecture upon the operations of medicines, I showed upon the living animal what are the effects of an introduction of a certain quantity of water at 104° Fahrenheit, into the veins. In making this experiment, it occurred to me to see what might be the influence of the artificial plethora which I produced, upon the phenomena of absorption. In consequence, after having injected almost two pints of water into the veins of a dog of ordinary size, I introduced into his pleura a small dose of a substance, with the effects of which I was familiar. I was surprised to see these effects only take place several minutes after the period at which they usually shew themselves. I immediately repeated the experiment upon another animal, and obtained a similar result.

" In another experiment, wherein I had introduced as much water (about four pints) as the animal could support without ceasing to live, the effects did not shew themselves at all; absorption had probably been prevented.

" I might also make the opposite experiment; namely, to diminish the quantity of blood, and observe whether absorption would then be more rapid: the event was exactly what I had foreseen. An animal was bled, and also deprived of about half a pound of blood;—the effects, which should not have happened before the end of the second minute, shewed themselves distinctly before the thirtieth second."

These experiments of M. Magendie illustrate the important effects which the different states of repletion and inanition produce on the system, accounting for its greater or less susceptibility to the impression of external agents upon it, and enabling us to understand how various conditions in these respects operate in modifying the function of absorption.

After long fasting, the quantity of fluids being diminished in the body, absorption is effected with greater facility, and substances are rapidly taken up and introduced into the system. Hence the greater risk of entering, when fasting, apartments occupied by persons labouring under contagious diseases, in consequence of the miasms emanating from them being more easily introduced under such circumstances.

All kinds of evacuents indirectly promote absorption, such as blood-letting, purgatives, medicines which augment the discharge of urine, and those which increase perspiration: they are therefore had recourse to by the medical practitioner in diseases where his object is to effect the removal of dropsical effusions, or morbid growths, and this they are calculated to produce by their double effect in diminishing the action of the arterial capillaries, and favouring the function of absorption.

Whatever tends to relax arterial tension, and to lessen the strength and tone of the system, is found to promote absorption, and conversely, whatever excites the action of the heart and arteries diminishes it. In this way nauseating emetics, exhibited with the view of causing vomiting when poisons have been received into the stomach, increase the danger, by favouring their introduction into the circulation, so that even if vomiting be excited, it may be too late, a sufficient quantity of poison to effect a fatal termination having been already introduced.

Mental causes operate in a similar manner; hence depressing feelings of the mind, such as fear, anxiety, and despair, favour the propagation of contagious disease, while confidence and hope act as conservative principles. It has therefore been observed that a dog is in much less danger from the bite of a viper when suddenly bitten, than when he has been for some time gazing at the reptile, and thereby more or less terrified by the sight.

From the consideration of facts like these, we may perceive the important results arising from the relative conditions of the different sets of vessels of the body, and mark the connection which subsists between these conditions and the functions to which the vessels are subservient.

On these grounds we can also partly understand how, on the exposure of two individuals to the same source of contagion, the one may escape while the other is affected, and likewise how the same individual may at one time resist the causes of infection, while at another he becomes subject to it, although under exactly the same external conditions of exposure.

CHAPTER VI.

SECRETION.

Preliminary Observations—Classification of Secretions—Matter of Perspiration—Scarf-skin serves as a barrier between the Body and the External World—The vast extent of the two general Mucous Membranes—Only one Mucous Membrane in Animals below the class of Mammalia—Gaseous Exhalations—Follicular Secretions—Unctuous Secretion of the Skin—Necessity of Personal Cleanliness—Liquor of the Eye-lids—Wax of the Ears—Musk, and other odorous Secretions of Animals—Glandular Secretions—Arrangement of the Glands—Tears—Effects of the passions and emotions of the Mind upon Lachrymal Glands—Why Women and Children shed Tears easily—Secretions connected with Digestion adverted to—Structure and use of the Kidneys—The very compound nature of the Urine—Urine carries off the superfluous, useless, and worn-out particles from the System—The quantity of Urine regulates the balance of Fluids in the Body—Sugar in the Urine—Urinary Concretions—Urinary Bladder—its Structure and Use—Partly under the control of the Will—Glandular Bodies, whose use has not been ascertained—Interstitial Secretion—Nutrition, Growth, and Renewal of the various Textures of the Body.

HAVING considered the agents by which the blood is distributed to the various parts of the body, the changes it is subjected to in its circulation through the lungs and system at large, the means of compensation for its expenditure, its character and constitution, and the manner in which both the old and new materials are taken up and introduced, we may now direct our attention to the nature and source of the different substances elaborated from it by the function of secretion.

No physical laws, either mechanical or chemical, as hitherto ascertained, will enable us to explain the mode of formation from the same fluid of the various gaseous, fluid, and solid substances of which living bodies consist, these products materially differing, as they do, not only from each other, but likewise from that from which they are derived. In the sap taken up by different plants, and in which, from whatever plant derived, chemists can detect not the slightest shade of difference, we see narcotic opium formed by the seed capsules of the poppy, the poisonous prussic acid by the leaves of the cherry-laurel, an emetic principle by the root of ipecacuan, a pure bitter in the strobiles of the hop. Acids are obtained from some, alkalies from others, sweet juices, nutritious fecula, and fixed or volatile oils from others. Even different parts of the same plants furnish peculiar secretions: the fleshy part of the fruit of the olive abounds with a bland oil, no trace of which can be detected in the sap of the vessels proceeding to the part in which it is formed, and the most minute examination of the tissue in which it is prepared has failed to furnish an explanation of the manner of its production. So likewise in animals we cannot tell how the nutritious milk is secreted in one organ, the bitter bile in another, the acrid urine in a third, and from others an offspring endowed with independent life for the continuance of the race; nor can we tell how the same individual, under the influence of disease, has established new secretions possessed of properties whereby they become capable of propagating themselves to an indefinite extent, such as from small pox, measles, and contagious fevers. The most careful and elaborate examination of the blood, from which these secretions are formed, throws no light on the processes by which they are effected, nor will the most delicate and searching analysis explain the origin of their essential qualities.

We say that the ultimate elements of animal bodies are chiefly hydrogen, carbon, oxygen, and nitrogen: they are termed elements because they have resisted all the means hitherto had recourse to for decomposing them; we are therefore entitled to hold them as elementary until they be shewn to be compound. Yet for any thing that is known they may in reality be composed of still more subtile principles, and regulated by laws of which at present we can entertain no conception. The compound nature of such as water and atmospheric air, not long ago considered as elements; the still more recent decomposition of the fixed alkalies and earths, as well as the simple constitution of others, such as chlorine, till lately esteemed compound; the powers possessed by electricity, as modified by friction, chemical action, magnetism, heat, and organic life; and the effects which heat and light are capable of producing, the investigation of which adds every day to our acquirements, all tend to show the uncertainty of human knowledge, and teach a lesson of humility in estimating the stability of the most universally received and generally established doctrines respecting the laws and operations of nature.

Although the means by which living organs effect these transmutations, and the immediate source of these seemingly creative powers baffle every attempt to unravel them; although the proximate causes of the peculiar qualities of their products, and in what these essentially consist, be entirely unknown;—admitting that these are provinces which cannot be cultivated with any prospect of success, that they are secrets which man cannot penetrate, mysteries which for the present at least are hid from his eyes, still the examination of the construction of the machinery by which they are produced, and the investigation of the properties characterizing them, are both legitimate and interesting fields of inquiry, and well repay the labour bestowed on their cultivation.

For the present we shall confine ourselves to the examination of those secretions which contribute to the preservation and wants of the individual, leaving for a future occasion the consideration of such as are subservient to the continuance of the race. Secretions may be arranged under four general divisions: first, exhalations where the thinner part of the blood is discharged from extended surfaces, including those from the skin, mucous, synovial, serous, and cellular membranes; second, follicular secretions from small crypts dispersed on the skin, and mucous membranes; third, glandular secretions, comprising the tears, saliva, pancreatic juice, bile, and urine; and, fourth, interstitial secretions, such as constitute the peculiar matter to each tissue, as that of bone, cartilage, ligament, muscle, nerve, &c.

Exhalations.—We have already had occasion to state (p. 85) that a large quantity of the watery part of the blood is daily discharged from the skin, forming the matter of sensible and insensible perspiration, and that it is of great importance in the regulation of animal heat. This discharge may depend on two causes—mechanical transudation, or exosmose, and vital action of the vessels, whereby a portion of the serous part of the blood escapes in quantity varying according to the state of the system and condition of the atmosphere. The cuticle or scarf-skin, spreading over the whole external surface of the body, affords a covering of greater or less porousness and density in different situations, forms a barrier between all that belongs to the body of the individual and the external world around him, and regulates to a certain extent perspiration. It is devoid both of blood-vessels and nerves, and is the product of the subjacent vessels; it forms numerous branched and reticulated lines or ridges, sometimes symmetrically arranged, as at the points of the fingers, and having intermediate fissures conspicuous in the palms of the hands. It is pierced with an infinite number of exceedingly minute perforations, termed pores, some of which give exit to the hair, through which the vapour exhales; but even independently of these pores, as shewn by the phenomena of endosmose and exosmose, membranes do not offer a complete obstruction to the passage of fluids. Being extravascular, its influence is entirely mechanical, and continues to operate even in the dead body. In temperate climates, it lessens evaporation from the dead body, and to a certain extent retards decomposition; but so rapidly does evaporation take place in the arid deserts of Africa and Arabia, that when the devoted caravan has been overtaken and destroyed by the blast of the burning simoom, the fluids are so instantly drunk up that the light and parched mummy which remains may continue for years without undergoing further change.

The true skin, which lies immediately under the cuticle, is highly vascular, and possessed of acute sensibility, and although defended by its covering, still it is not beyond the influence of external agents which come in contact with the external surface of the body, and which affect the condition of its vessels; for, on the application of several substances, these become excited, and exhale a greater quantity than usual of the serous part of the blood. Thus heat, friction, and various other stimulants, promote this discharge, and the quantity poured out may be so abundant that it cannot obtain a sufficiently ready escape through the scarf-skin, and therefore accumulates beneath it, raising blisters which may appear in a few seconds, as from the application of boiling water. The action of the vessels distributed on the surface of the true skin is also affected by the state of the system, in all its various conditions of health and disease, or as under the influence of medicinal and other agents. The quantity and quality of the blood likewise have their effect. Some parts of the body also perspire more freely than others, as the palms of the hands, and the soles of the feet. Thus we perceive that perspiration, whether sensible or insensible, is regulated by the condition of the atmosphere, the state of the cuticle, of the true skin, and system at large. So far as it depends on the two last, it may be considered as more affected by vital than mechanical agency.

The vessels of the skin likewise secrete carbonic acid, as proved by keeping the arm in a jar, so managed as to prevent the renewal of air in the jar; after some time an additional quantity of carbonic acid will be found to have made its appearance. This secretion of carbonic acid, and where it is lost at the cardiac opening of the stomach; while in some animals, as in the horse, it may be traced over the cardiac portion of that organ. It lines the three first stomachs of ruminants, and the gizzard of birds.

In some situations the mucous membrane is thicker than in others, for example, in the nostrils, where it is soft and exceedingly vascular. In other parts it is folded so as to extend the surface still further, as in the intestinal canal; and in the smaller intestine it is furnished with downy nap, whereby the contents are retarded, and the surface of absorption and secretion much extended.

Throughout the whole extent of the mucous membrane watery exhalation is constantly carried on, so as to preserve the surface moist. The amount of watery fluid extricated in breathing, and the purposes to which it is subservient, we have already had occasion to examine, when treating of respiration.

The carbonic acid from the lungs is strictly to be considered as a secretion, and in the same light the discharge of various accidental substances, which emanate from the air passages, according to the matters taken into the stomach, imparting to the breath their characteristic odour, or, in disease, where the air of expiration becomes loaded with tainted and infectious vapours.

In like manner, the arteries of other mucous membranes pour out a thin secretion, so as to preserve them moist, as is more especially observed in the stomach and intestinal tube. In the former, as has been already shewn, it is possessed of remarkable and peculiar properties, whereby it performs an important part in the office of digestion, under the name of gastric juice; and in the latter there is reason to infer that it serves an essential purpose, as secreted from the different parts of the intestines. In the stomach and bowels it is liable to be increased or diminished in quantity, or vitiated in quality, by various causes.

Along the course of the alimentary canal various gaseous exhalations are given off, especially in deranged conditions. Of these gases, carbonic acid is evolved principally in the stomach and small intestine, and its discharge is considerable in the lower tribes of animals, whereby the office of the lungs or gills is vicariously performed. In the lower bowels the gases disengaged are chiefly carburetted and sulphuretted hydrogen.

An analogy of structure and function is thus observed to obtain between the skin and the whole extended surface of mucous membranes, accounting not only for the close sympathy which subsists between them in a state of health, but likewise for the connections established among them in a deranged state, and the similarity in the characters of the diseases to which they are liable.

The serous sacs, synovial and cellular membranes, having been generally described in the last chapter, the properties which characterize them, and the balance which subsists between their secreting and absorbing functions pointed out, it is unnecessary further to treat of them at present.

Follicular Secretions are of two kinds: first, an oily or sebaceous matter poured out upon the surface of the body for the purpose of preserving it soft and pliant, and defending it from moisture; secondly, the fluid furnished by the mucous glandules dispersed over the mucous surfaces. The sebaceous secretion is formed in small glandular bodies implanted in the skin, and having a resemblance to little globular bottles with short necks, the latter serving the office of excretory ducts, while in the former the secretion is prepared and retained till required. Sometimes it accumulates till it becomes so thick and consistent that it cannot be readily expelled; it then produces irritation and inflammation, and a pimple is the consequence. At the sides of the nose and other parts of the face, sebaceous crypts are easily seen. The matter they contain occasionally becomes blackened where it comes in contact with the air; and when squeezed out, presents the appearance of a small white worm with a black head. Generally the hairs traverse the cavity of a follicle in their direction outwards; and when the beard begins to sprout, the stripling's face often becomes disfigured with pimples, caused by the irritation and swelling of these crypts. Errors of diet and various deranged conditions of the system produce a similar effect.

The sebaceous follicles furnish likewise a volatile odour, or rather perhaps the sebaceous secretion is itself partly odorous and volatile, becoming thickened and having its scent diminished by evaporation; in the flexures of joints, especially in the arm-pits, groins, and other parts, the crypts are large and numerous, and emit a peculiarly characteristic odour. The quantity and character of the sebaceous secretion vary much in different individuals, and in the same individual in different conditions of health. The different varieties of mankind are distinguished by their peculiar odour, and the activity of these small glandules is much greater in some cases than in others. Heat promotes the secretion of sebaceous matter; accordingly the inhabitants of hot climates produce a greater quantity of it than those of cold and temperate regions.

This oily or unctuous substance performs an important purpose in preserving the skin in a proper condition for the performance of its functions, and defending it especially from the effects of moisture. It is apt, however, to accumulate on the surface, and likewise to cause the adhesion of particles of dust, producing a sordid condition of the skin, and of the clothing immediately in contact with it. Hence the absolute necessity not only of properly washing the body itself, but likewise of a frequent change of the inner clothing. From the unctuous nature of this secretion, water alone is not sufficient for its removal; therefore soap becomes requisite, although detergents of this nature, from their effects upon the skin, ought to be used sparingly, and only in their mildest forms.

Along the margin of each eye-lid there is a row of crypts like a string of beads, larger and more numerous in the upper than in the under eyelid. They belong to the follicular glands, and furnish a thick viscid fluid for keeping the eyelids sufficiently slippery and smooth, and preventing the tears from trickling over the margin. Occasionally one of these little bottles becomes inflamed, producing the affection known by the name of Stye, which is generally accompanied with greater pain and constitutional disturbance than might be expected from a cause apparently so slight. The acuteness of the inflammation, however, and the exquisite sensibility of the part, sufficiently explain this. Sometimes the stye becomes indolent, and remains a very long time, permanently disfiguring one of the most beautiful features of the countenance, shewing that even a trifle like this should not be neglected.

The external passages to the ears present us with another variety of follicular crypts for the secretion of the wax. They form a cluster of small glandular bodies, occupying about one-half the length of the canal. The secretion they furnish, termed the wax of the ear, is of a resinous nature, and yellowish colour, with a heavy disagreeable odour and nauseous bitter taste. Its resinous character facilitates the transmission of sound, while an oily or mucilaginous fluid would have diminished the vibrations, so that it serves the purpose that the rosin does to the bow of the violin; at the same time it repels moisture, and, from its odour and taste, prevents the entrance of insects.

In several of the lower animals, certain follicular glands are found, which, instead of being solitary, are formed into compound glands, as in the beaver, musk-deer, and civet. The secretions furnished by these compound follicular glands are of a volatile and resinous nature. Generally they have an exceedingly penetrating smell; some of them being grateful, are employed as perfumes, for which purpose musk is highly prized; others are so abominably disgusting that they constitute the principal means of defence of the animal, as in the skunk of North America, which when pursued emits a discharge upon the enemy which at once disarms him. Clothes on which they have been ejected can never be thoroughly cleansed, and are therefore rendered utterly useless.

The second class of follicular glands are those belonging to mucous membranes. In their structure they resemble the sebaceous crypts. They are found every where scattered over the surface of mucous membranes, either singly or in groups, varying in their size in different situations. In some places they are collected into one bundle, thus forming a compound gland, as in the almonds of the throat. The fluids to which we have already had occasion to refer, as poured out from the mucous surfaces, so far as their chemical constitution shews, differ but little from the serum of the blood, and appear to be derived immediately from the vessels, without the intervention of any peculiar structure; while the thick viscid tenacious matter which is spread over the mucous membrane owes its distinguishing character to a peculiar substance not recognised in the blood, and elaborated from appropriate organs: to this the term mucus is strictly applied.

The following are the most important properties of mucus according to Berzelius. It swells and acquires apparent fluidity in water, without being actually dissolved, but gives a ropiness to it when present to a less amount than one per cent. With pure water at the temperature of 95° this appearance ensues in a few hours; but if the apparent solution is filtered, the mucus remains upon the paper, and gradually thickens. It may be repeatedly dried and moistened without material change of properties; it however becomes less transparent, yellow, and at length has a purulent appearance. When boiled in water it does not harden and shrink, but becomes tough, and on cooling is found to retain its former characters. When dried it is yellow and translucent; and subjected to distillation it yields carbonate of ammonia and empyreumatic oil; and phosphate and carbonate of lime and a trace of carbonate of soda are found in the residuary ash.

Mucous secretion, besides containing mucus, holds various salts in solution, and there are also found in it traces of albumen and osmazome. The serous exhalations, like the serum of the blood, display alkaline properties, while the mucous secretions are either neutral or acid.

Mucus serves as a defence to the surfaces which it covers, and is variously subservient to the functions performed by the different parts on which it is poured out. It facilitates the motions of the eyelids, and of the contents of the alimentary canal; it aids in the exercise of the smell and taste; it defends the gall-bladder and urinary passages from the acrimony of their contents, and in various other ways contributes to the functions carried on in the animal machinery.

Glandular Secretions.—Glands are organs composed chiefly of the ramifications of blood-vessels. The mode of distribution of the vessels not only varies in different glands, but in the same gland in different animals. They are surrounded with a covering of condensed cellular membrane, which constitutes their proper coat. Where the gland separates from the blood a fluid which is to be conveyed off, it is furnished with tubes for this purpose, termed excretory ducts. These are distributed through the glands variously according to the nature of each. The glands, which are thus supplied with excretory ducts, and which demand our attention for the present, are the lachrymal glands in the orbits of the eyes, those which have their secretions transmitted into the alimentary canal, and those subservient to the secretion of urine.

In each orbit above the external angle of the eye the lachrymal gland is situated in a slight depression. It is about the size of a small filbert, and composed of a number of granules connected with each other through the medium of cellular membrane; from these granules proceed little tubes for carrying off the tears as formed in the gland, and terminating by six or seven ducts, about two or three lines from the margin of the upper eyelid towards the temple. By the movements of the eyelid the tears are diffused over the anterior surface of the eye, so as to preserve it sufficiently moist for the due performance of its office, and also to wash away any light particles of dust that may fall upon it. When the two eyelids come in contact they do so only at their outer edges, there being left a little gutter posteriorly, along which the tears flow towards the internal angle, where there is placed in each eyelid a small pore, which can easily be seen by drawing down the lower lid, and looking at its margin close to the termination next the nose. These lachrymal pores are the orifices of two channels which convey the tears into a small sac, from which they are transmitted by a duct to the nose, where by the current of air they are soon evaporated, after having moistened the nasal membrane. All these parts derive their sensibility from the same nerve; accordingly we observe how intimately they sympathize with one another. On the application of any irritating cause to the surface of the eye, the lachrymal glands are excited, and the tears are more abundantly secreted. Pungent substances exciting the lining of the nostrils call forth the sympathy of the organs, and the tears flow copiously. When we are asleep, the eyes being closed, evaporation is prevented, and the lachrymal glands have rest, but no sooner do we open our eyes than, stimulated by the air and light, they are again roused into action.

No organs of the body so clearly and strikingly display the effects of the passions and emotions of the mind upon the corporeal frame as the lachrymal apparatus. A moderate degree either of the joyful or depressing emotions is accompanied with the copious shedding of tears; while either joy or overwhelming grief produce their suppression, and we know that relief is come, that sorrow is abated, when the tears begin to flow. During infancy and childhood tears are shed more readily, both from the greater abundance of fluids, and from the greater susceptibility of the young. For the same reasons too the female weeps from slighter causes than the more arid and impenetrable male: his manly pride and more determined character also operate in suppressing such external marks of emotion and feeling.

Having, in the chapter on digestion, considered the various fluids which are poured into the intestinal canal, it is unnecessary for us again particularly to advert to them. We have seen that three pairs of glands furnish the saliva to be mixed with the food in the mouth; that the pancreas transmits its secretion by a duct into the duodenum; that the bile secreted from the blood of the vena portæ, in its transmission through the liver, affords the only example in the human body of a secretion from venous blood; that in the gall bladder the bile undergoes certain changes, and has added to it a secretion from the arteries of that sac, according to some it being here that the bile derives its bitterness, which must therefore be considered as obtained from arterial and not from venous blood; we have observed further that the biliary duct terminates like the pancreatic in the duodenum, to meet with the chyme from the stomach; and that all these glands are excited by their appropriate stimulants, so as to be roused into action at the proper time, and to the necessary extent.

The kidneys, by which the urine is secreted, are situated in the loins, at the posterior part of the cavity of the abdomen, by the sides of the vertebral column, and surrounded with a loose cellular membrane, usually loaded with a considerable quantity of fat, the right being placed somewhat lower than its fellow of the opposite side. The kidney is of a somewhat ovoid form, a little compressed posteriorly, and more convex anteriorly, with its outer border convexly rounded, and the inner presenting a fissure for the entrance and exit of the vessels and nerves. On making a horizontal section of the kidney we perceive it to be constituted of two portions. The external, superficial, or cortical substance is of a dark purple colour, and composed of an infinite number of ramifications of blood vessels. The central or medullary part is formed of numerous straight tubes, which are collected into conical bundles or nipples. The number of these nipples corresponds with the number of glands of which the kidney originally consisted, for in the fœtus the kidney is divided into a number of distinct lobes, usually from twelve to fifteen in the human subject. The lobulated structure continues throughout life in some animals, as in the ox. In others, as in the whale tribe, seals and bears, when divested of the loose external covering, the kidney presents a striking resemblance to a bunch of grapes. The blood-vessels of the kidney are very large in proportion to its size, its artery being one-eighth of the calibre of the aorta. From its short course, and the peculiar distribution of its branches, it is well adapted for quick and copious secretion, readily accounting for the great abundance of fluid which it so speedily separates from the blood. The extreme arterial divisions are tortuous, and freely communicate with the accompanying venous twigs, so that injections readily pass from the one into the other. They open freely into the excretory duct, so that on introducing a pipe into the artery of the kidney, and injecting it with water, we find the latter flowing copiously into the vein on the one hand, and through the ducts on the other.

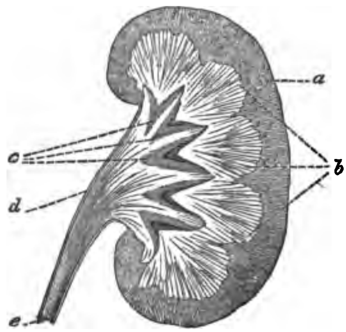

FIG. 18.

The conical nipples, formed by a collection of tubes, are each surrounded by a little cup, into which the urine trickles from the tubes. Several cups again form larger ones, termed funnels, which are united into one general reservoir, called the basin, from which the urine is conveyed by a duct, named ureter, into the appropriate receptacle, the urinary bladder.

In the engraving, *a* represents the cortical portion; *b*, the nipples; *c*, funnels; *d*, the basin; and *e*, the ureter.

The urine is by far the most compound of the fluids separated from the blood, draining off as it does particles of every tissue which the absorbents take up from all parts of the body, as worn out, redundant, and useless. The kidneys also afford the most ready passage for the evacuation of various substances introduced into the system in food, drink, and as medicines, which may easily be detected by their colour, odour, or appropriate chemical tests. Thus, in a very short time after being swallowed, rhubarb, logwood, madder, cochineal, litmus, soon display themselves by the tints they impart to the urine. Camphor, ether, and musk are detected by their odour. Oil of turpentine gives the smell of sweet violets, and by the use of asparagus a peculiarly disagreeable odour is given off from the urine. Nitre, prussiate of potash, iodine, mercury, and various other chemical substances, are ascertained with facility by having recourse to their proper tests. Mr Brande gives the following list of substances as being found in healthy urine:

1. Water.
2. Carbonic acid.
3. Phosphoric acid, or super-phosphate of lime.
4. Uric acid, or super-urate of ammonia.
5. Phosphate of lime.
6. Phosphate of ammonia.
7. Phosphate of soda.
8. Phosphate of magnesia.
9. Common salt.
10. Sulphate of soda.
11. Albumen.
12. Urea.

To which he adds,

13. Fluoric acid.
14. Benzoic acid.
15. Acetic or lactic acid.
16. Gelatin.
17. Lactate or acetate of ammonia.
18. Sulphate of potassa.
19. Fluate of lime.
20. Muriate of ammonia.
21. Sulphur.
22. Silica.
23. Mucus.
24. Colouring and odorous matter.

In operating chemically upon so complicated a fluid as the urine, it is extremely difficult to distinguish between what may merely be the result of the processes to which we subject it, and those substances which really form a part of its constitution. It is also very difficult, with any degree of accuracy, to ascertain the relative proportions of the different ingredients. Indeed these vary according to such a variety of circumstances, that the results of no two operations are found to furnish more than an approximation to each other. The following table given by Berzelius will serve as an example of the result of one such examination.

Water	933.00
Urea	30.10
Sulphate of potassa	3.71
Sulphate of soda	3.16
Phosphate of soda	2.94
Muriate of soda	4.45
Phosphate of ammonia	1.50
Free lactic acid (acetic) Lactate of ammonia (acetate) Animal matter soluble in alcohol Urea, not separable from the preceding	17.14
Earthy phosphates, with a trace of the fluate of lime	1.00
Uric acid	1.00
Mucus of the bladder	0.32
Silica	0.03
	1000.

Of the articles in the above list, urea is that which imparts to the urine its principal peculiarities. When obtained perfectly pure it is transparent and colourless, with a peculiar cooling taste, and a faint but not urinous smell; it is soluble in about its own weight of water at 60°; it displays neither alkaline nor acid effects upon vegetable colours, but unites with some of the acids, such as the nitric and oxalic. Urea is a proximate animal principle, composed of four elementary bodies, viz. carbon, hydrogen, oxygen, and nitrogen. The last of these constitutes nearly one-half of its weight. The present advanced state of chemical science, and the philosophic views which now direct chemical operations, are strikingly displayed in the artificial preparation of urea, by acting on cyanate of silver or of lead with ammonia, affording the first instance in which success has crowned the various attempts which have been from time to time made in order to imitate by art the products of nature.

Uric acid is another of the ingredients deserving particular notice. It is composed of the same elements as urea, though in different proportions; it is nearly insoluble in water; when perfectly pure it forms a white, tasteless, inodorous substance. In combination with various bases, especially with ammonia, it is found in the urine of all animals, but more abundantly in the carnivorous than herbivorous. In serpents, as in the boa constrictor, the secretion from the kidneys is voided in the solid form, and consists chiefly of uric acid.

The kidneys, constituting as they do important emunctories or channels by which superfluous and hurtful matters are discharged from the blood, it is necessary that their function should be carried on without intermission, as is found to be the case during health. We have seen that the system is freed from excess of carbon by the secretion of carbonic acid from the lungs. The discharge of bile likewise tends to the purification of the blood; and we now find that through the kidneys, in the secretion of urea and uric acid, any redundancy of nitrogen is readily got quit of, the constant depositation of new, and absorption of the old materials (for our body is not the same for two consecutive days, nay hours, or even minutes), demands the unceasing evacuation of these old worn-out particles from the general mass of circulating fluids, although, for the comfort and convenience of the animal, means are adopted to obviate the necessity of constant discharge from the body by the provision of an urinary reservoir, in which it may be lodged and accumulated till a fitting opportunity offer for its expulsion.

The purposes served by several secretions render their constant production unnecessary, as the tears, the saliva, and the gastric juice; while the secretion of carbonic acid from the lungs cannot be suspended for a minute or two during the continuance of our existence after birth without the most imminent danger to life. Neither can the function of the kidneys be suspended for any length of time without injury. Although during sleep, from the discharge by the skin being more copious, there is a less quantity of urine secreted, yet it will be found to contain a greater proportional quantity of the salts and animal matters by the discharge of which the purity of the blood is preserved, than that which formed during the day, thus preserving an uniformity in this respect. Where the function of the kidneys is suppressed by disease, or where they have been extirpated by way of experiment in the lower animals, the formation of urea and of uric acid does not become altogether suspended, for in such cases they have been detected in the blood—shewing that though the kidneys constitute the proper channels for their discharge, still they are not absolutely essential to their preparation.

Of all the substances formed in the animal body, none are so liable to decomposition as urea; and of all the fluids, the urine is that which hastens most speedily into a state of putridity. When its secretion is suspended, or when its evacuation is obstructed, great distress is soon experienced in the whole system; symptoms of decomposition commence before the extinction of life; and when death takes place, the body rapidly passes into a state of offensive putrefaction—indicating how important to the health and well-being of the whole frame the due performance of the function of the kidneys necessarily is.

By the tables which we have introduced, it will be seen that saline and other matters discharged by the urine are very various. The quantity of solid contents which are discharged in this way amounts to about fifteen drams in the twenty-four hours. The average specific gravity of healthy urine is about 1020 to 1025; in some instances it is little more than that of simple water, while in certain diseased states it rises to 1030, and occasionally even to 1040.

The function exercised by the kidneys is one of the most important of the compensating functions; or, in other words, the urinary secretion is of great use in preserving a proper balance in the system, and enabling it readily to accommodate itself to the great variety of circumstances to which it is exposed. We have had occasion to advert to the connection which subsists between the state of the skin and the quantity of urine discharged. In dry warm weather and in hot climates the fluids are determined to the surface, where they are discharged in the state of vapour, thereby reducing the temperature of the body. In winter, on the other hand, and also in a damp atmosphere, the cuticular discharge is diminished, while that of the urine is augmented. In cold damp climates the kidneys are therefore the most active, while in tropical countries the skin is most excited; and it is interesting to observe that in the former, diseases of the urinary organs predominate, while in the latter derangements of the skin chiefly prevail. The quantity of urine is materially affected by the quantity of food, and especially of drinks, so that a due proportion of fluids in the body is thus regulated. Where there is great expenditure in other directions, or increased evacuations by other channels, this secretion is diminished, and conversely, when discharges from other parts become lessened, an increase of urine takes place. Various substances possessing the property of exciting the action of the kidneys and promoting the secretion of urine, are therefore termed diuretics, and are of essential use to the physician in the treatment of several diseases.

In the healthy state, the urine, when first evacuated, possesses acid properties; but on standing, in a very short time chemical changes are effected, whereby it is rendered alkaline. The alkali elicited is the volatile, or ammonia. From its alkaline quality, stale urine is employed in manufactures as a detergent, especially in cleansing woollen cloth. The urine of cattle forms an excellent top-dressing for meadows; that of birds, voided along with their excrement, contains a considerable quantity of the carbonate of lime, and forms the best manure for the cultivation of several vegetables. Mr Morier observes, "The dung of doves is the dearest manure which the Persians use; and as they apply it almost entirely to the rearing of melons, it is probably on that account that the melons of Ispahan are so much finer than those of other cities. The revenue of the pigeon-house is about a hundred tomauns per annum; and the great value of the dung, which rears a fruit which is indispensable to the existence of the natives during the great heats of summer, will probably throw some light on that passage of Scripture, where, in the famine of Samaria, the fourth part of a cab of dove's dung was sold for five pieces of silver."

As the urine carries off from the system the debris of the body, so does it vary in different states of the constitution. In children and in nurses, the phosphate of lime, which constitutes the earthy matter of bones, scarcely appears in this secretion, being determined to the formation of bone in the one and milk in the other, while in old age this earth becomes abundant, from its excess in the body at large. In some morbid conditions the phosphate of lime, instead of being deposited in the formation of bone, is discharged by the urine, whereby the bones become flexible, and incapable of supporting the weight of the body: hence distortions of various parts, particularly of the spine, pelvis, and lower limbs, as in rickets.

In some cases new formations appear which do not exist in healthy urine. Of these sugar forms one of the most remarkable; it occurs in one of the forms of the disease called *diabetes*, in which there is a prodigious quantity of urine secreted, accompanied with an insatiable thirst, and most voracious appetite; and although these may be freely indulged, still the body rapidly wastes, from the inordinate expenditure to which it is subjected. Diabetic sugar is granular, resembling grape sugar in its appearance, composition, and properties. In another form of diabetes, the urine is equally excessive, but without the presence of sugar, and the formation of urea is suspended. The leanness and dryness of the whole body in these diseases, where the fluids are drained off in this way, is the opposite of what takes place where the action of the kidneys is diminished or suppressed, where effusions take place in the shut sacs, and in the cellular membrane, forming the different varieties of dropsy, according to their situation.

Another occasional formation in the urine is oxalic acid, so named from its existence in the wood-sorrel. It may be got from several other plants; but for the various purposes of art, it is found more economical to form it artificially than to elicit it from those combinations in which it is produced by nature; it is therefore procured by the action of nitric acid on sugar. This conversion of sugar into oxalic acid, and the occasional appearance of sugar in the urine, throws some light on the probable occurrences which give rise to oxalic acid in the urine. From the great affinity which exists between oxalic acid and lime, it attracts the lime in the urine, and an insoluble compound is formed, producing one of the forms of urinary concretions, or *calculi*, as they are termed. From the rough and dark-brown appearance which it usually presents it is called the *mulberry calculus.*

The great quantity and variety of saline and crystallizable ingredients in the urine account for the frequency of urinary concretions, giving rise to sabulous or gritty deposits, gravel or calculi. These deposits are frequently temporary only, and may be produced by a variety of accidental causes which influence the secretion of urine; but when they are more or less constant, or arise from apparently trifling causes, they then require the utmost attention, as being the frequent forerunners of stone. The tendency to the depositation of gravel is generally first observed in the urine as it cools, but it afterwards increases to such an extent that the urine is voided more or less turbid. The composition of urinary concretions is very various, as might be expected from the great diversities which obtain in the condition of the urine, according to different states of the system. Of these uric acid is by far the most common: generally it is in combination with ammonia, producing a brick-coloured deposit or *red sand*, or agglutinated into masses of variable sizes, forming gravel or stone. The next most common are those composed of phosphoric acid in union with lime, ammonia, or magnesia, either as binary, ternary, or quaternary compounds. They produce a white sabulous deposit from the urine or *white sand.* The oxalate of lime, carbonate of lime, and several others, occasionally present themselves.

These distressing affections are more liable to occur at the commencement and towards the decline of life than during middle age. In childhood the rapid renewal of parts in the growth of the body, and the consequent removal of old materials, the activity of the digestive function producing an accumulation of matters in excess, call upon the kidneys for the full exercise of their action. While in old age an excessive formation of bone-earth takes place, as is shewn by the tendency to its depositation in cartilages, blood-vessels, and membranes. The cuticular action is also diminished, so that the kidneys require again to exert their function to the utmost. Cold damp climates also predispose to the formation of urinary calculi, by checking the action of the skin, and thus throwing a greater burden upon the kidneys. We therefore find that they are extremely prevalent in Britain and Holland. In the latter country a surgeon of the name of Raw is said to have cut for the stone fifteen hundred patients successfully.

The urine presents great varieties in colour, consistency, and quantity in different diseases. Albumen is a common ingredient in healthy urine, but always in a very small relative proportion; in some cases of disease it is so abundant as to coagulate by heat, or even sometimes spontaneously within the bladder; it is also recognised by the precipitate it affords by proper tests; but in applying those tests, and indeed generally in judging of the state of the urine of any individual, it should, if possible, be previously ascertained that it is not naturally subject (which is at times the case) to excess or deficiency of this or other of its components. In some forms of dropsy, especially where there is disease of the kidneys, excess of albumen is often observed; in these instances the urine is scanty, and its specific gravity below the usual average, in consequence of deficiency of urea and saline matter.

As the constant discharge of the urine from the body would be both inconvenient and offensive, a reservoir is provided for its reception in the urinary bladder, which is situated in the pelvis, in front of the rectum. In its form it is somewhat of a compressed oval, though its shape varies in different ages and sexes. It receives a partial investment of peritoneum at its upper part. It is essentially composed of a muscular layer externally, and an internal mucous covering, with the interposition of cellular membrane. The muscular fibres are curiously interwoven with each other. The general direction of the external fibres are from below upwards, others are oblique, while the internal pursue a transverse or circular direction. At its lower part these fibres are more numerous, especially the circular, so as to form a sphincter for the retention of the urine. The mucous lining when the bladder is empty is folded into ridges, but these disappear when it is distended. It is supplied with blood from the neighbouring vessels, and its nerves are derived from two sources, being twigs from the great sympathetic connected with its organic life, and others from the extremity of the spinal cord, by which we possess voluntary power over the bladder in the retention and expulsion of the urine. As the urine is secreted in the kidneys it is conveyed by the tubes named ureters into the bladder. The ureters are endowed with a certain degree of contractility, though little contraction is necessary for the transmission of the urine in ordinary cases. They proceed to the lower part of the bladder near its neck, and penetrate its coats obliquely, this obliquity of entrance serving the purpose of a valve, so as effectually to prevent the return of urine from the bladder. Even in the dead state, when the bladder is fully distended with air, none of it can escape by the ureters, so completely does this valvular contrivance operate.

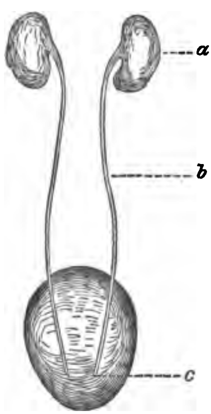

FIG. 19.

In the engraving, *a* represents a kidney; *b*, an ureter; and *c*, its termination near the neck of the bladder.

In the whale tribe the urinary bladder is comparatively small. In a porpoise, ten feet in length, the bladder was not larger than that of a rabbit. The element in which these animals exist probably renders the frequent evacuation of urine less inconvenient. The urinary bladder is confined to the class of mammalia. In birds, reptiles, and fishes, the ureters terminate in a reservoir common to them, the rectum and genital organs, and known under the name of cloaca. The urine of birds is voided along with the feculent matter of the intestines, and is generally of a whitish colour, from the abundance of carbonate of lime it contains.

By the gradual accumulation of urine, the bladder is distended, when its sensibility becoming excited, we are warned to relieve it. Being accustomed to the presence of the urine, and also being protected by the mucus from the internal coat, it suffers it to collect to a certain extent, but when the urine is unusually acrid from the exhibition of medicines or other causes, or where the sensibility of the bladder is preternaturally acute, the calls become more frequent and urgent. On the other hand, when its sensibility is impaired, as often happens in old age, the urine sometimes accumulates to such an extent as to paralyze the muscular coat, and the most powerful straining of the muscular walls of the abdomen are inadequate to afford relief though they co-operate efficiently in the healthy condition of the parts.

Before leaving the glands some notice may here be taken of certain bodies which are usually classed along with them, but of the functions of which we are ignorant. These are the pineal and pituitary glands within the skull, the thyroid body on the anterior part of the windpipe, the thymus gland in the chest, and the supra-renal capsules in the abdomen.

Those glands which are destined for the formation and separation of matters from the blood being furnished with excretory ducts and other appendages, we can readily avail ourselves of opportunities for collecting the fluids which they elaborate. We can examine the physical properties of these fluids, and subject them to various chemical and mechanical processes, by which we become acquainted with their distinguishing characters. We are enabled to pursue them to their destination, and draw conclusions as to the final purposes to which they may be subservient. But in the investigation of the use of such glandular bodies as do not separate any fluid from the blood, the difficulties met with have been hitherto insuperable. Late observations on the glands in the course of the absorbents, and on the spleen, have tended to throw some light on their uses, to which we have had occasion already to direct our attention.

The Pineal Gland is a small conical-shaped body, from which circumstance it has derived its name, from its form resembling the cone of a pine. It is of a dark grey colour, and situated towards the base of the brain. The celebrated Descartes conjectured, it being a single organ attached by nervous cords, and placed nearly in the centre of the brain, that it formed the peculiar seat of the soul. The conjecture appeared supported by the fact, that in the brains of certain idiots a quantity of earthy matter was found, which was supposed to interfere with the manifestation of the mental faculties; but when it was ascertained that in almost every pineal gland, whether belonging to the idiotic or the most intelligent, such concretions may very frequently be found without the slightest trace of connection with deranged action, the doctrine of this being the peculiar seat of the soul was abandoned, and we still remain ignorant of its use.

The Pituitary Gland is situated in a depression on the internal surface of the base of the skull, lying between the dense lining of the bone and the serous membrane called the arachnoid. At one time it was believed to serve as a sewer to the brain, discharging its excretions through the nostrils, from which conjecture it derives its name. It is still a vulgar belief that there is a direct connection between the nose and the brain, and that discharges take place in this way to the relief of the latter; so true it is that popular notions are generally nothing more than the cast-off opinions of former philosophers.

The Thyroid Gland is situated in the front and by the sides of the windpipe, immediately below the larynx, and is abundantly supplied with blood. Strictly there are two thyroid glands, though their close approximation gives frequently the appearance of a single body. This body is the seat of the disease known in this country under the name of Derbyshire neck. It is not unfrequent in the valleys of the Alps, where it is termed goître: it is also endemic in other mountainous regions.

The Thymus Gland is placed in the anterior part of the chest, immediately behind the breast-bone. It is not only proportionally but absolutely larger at birth than in the adult, and even entirely disappears in advanced life. It is therefore justly inferred that it performs some office in the fœtus which is either not necessary after birth, or that it is subservient to some temporary vicarious function, but what that may be does not yet appear. We dissected a marmot some years ago, in which the thymus was exceedingly large and fully organized, although the animal was of adult age. We should therefore suppose that investigations as to its use might be pursued with greater chance of success in that animal than in any other.

The Suprarenal Capsules are bodies so named from their situation above the kidneys. Like the thymus they are large and of a granulated texture in the fœtus, while in the adult their size is considerably diminished and their texture altered, becoming cellular, and containing a dark-coloured fluid. When humoral doctrines were in vogue—when it was believed that the temperament of the constitution, the character of disease, and the mental condition depended on the state of the fluids—a gloomy desponding state of the mind was ascribed to a black bile which was supposed to be furnished by these glands: hence our word melancholy, from μελας, black, and χολη, bile; and for this reason also these bodies were termed atrabiliary glands.

Interstitial Secretion.—In the extreme capillary vessels of every tissue of the body there is deposited the peculiar enabled to pursue them to their destination, and draw conclusions as to the final purposes to which they may be subservient. But in the investigation of the use of such glandular bodies as do not separate any fluid from the blood, the difficulties met with have been hitherto insuperable. Late observations on the glands in the course of the absorbents, and on the spleen, have tended to throw some light on their uses, to which we have had occasion already to direct our attention.

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The Thymus Gland is placed in the anterior part of the chest, immediately behind the breast-bone. It is not only proportionally but absolutely larger at birth than in the adult, and even entirely disappears in advanced life. It is therefore justly inferred that it performs some office in the fœtus which is either not necessary after birth, or that it is subservient to some temporary vicarious function, but what that may be does not yet appear. We dissected a marmot some years ago, in which the thymus was exceedingly large and fully organized, although the animal was of adult age. We should therefore suppose that investigations as to its use might be pursued with greater chance of success in that animal than in any other.

The Suprarenal Capsules are bodies so named from their situation above the kidneys. Like the thymus they are large and of a granulated texture in the fœtus, while in the adult their size is considerably diminished and their texture altered, becoming cellular, and containing a dark-coloured fluid. W[illegible] ral doctrines were in vogue— when it [illegible] temperament of the consti- tu[illegible] the mental condition [illegible] gloomy desponding [illegible] lack bile which was [illegible] lands: hence our word [illegible] and χολη, bile; and for [illegible] s were termed atrabiliary

[illegible]—In the extreme capillary vessels [illegible] ody there is deposited the peculiar matter belonging to each. Thus in bones the osseous substance is elaborated, in cartilage cartilaginous matter, in muscle muscular fibre, and so on with every organ in the body, as the nervous system, the glandular, the membranous, and the cuticular. Every tissue of the body has the blood distributed to it in a manner adapted to its organization and to the function it has to exercise, so as to supply it with a greater or less quantity, with different degrees of velocity and with different degrees of force. While it passes through these exceedingly minute tubes, which are invisible to the naked eye, the matter belonging to each is separated, just as we find the bile separated from the blood of the vena portæ in the liver, the urine from the vessels of the kidneys, or the saliva from the salivary glands. The blood containing, already formed, a great number of the materials which compose the majority of the tissues, such as fibrin, albumen, muco-extractive phosphates of lime and magnesia, and various other salts, it may be supposed that simple separation alone takes place. This indeed may be the case to a certain extent, but it will not explain, after all, how the vessels are endowed with the power whereby they are enabled to select from the general mass of blood that particular matter which is required. On the other hand, several substances are found in the animal textures which cannot be recognised in the blood, as gelatin, the nervous matter, and even fat; for the oil found in the blood is probably derived by absorption from the adipose cells. It must therefore be admitted that the vessels of those textures which contain substances not recognisable in the blood possess the power of forming them. At the same time we cannot acknowledge them to be endowed with any thing like creative power. The elements of which these animal products are formed must exist in the materials from which they are prepared, and must ultimately be derived from without. In whichever way the proximate principles of the different tissues are derived, whether by the separation of matter already in the blood, or by the formation from it of the elements of which they are composed, we have afforded us in the admirable perfection with which the processes are conducted, and their excellent adaptation to each individual organ and condition of that organ, proof of the supreme power, wisdom, and prescience, which have arranged and contrived them.

The separation and depositation of the peculiar matter belonging to each individual tissue has been termed *nutrition*, instead of secretion. The term nutrition has been applied to the separation of solid matter from the blood, while secretion is applied to that of fluids, and in a still more restricted sense to the separation of fluids by glands. It appears to us that there is not only no advantage, but even a disadvantage, in using different terms to indicate the states in which the different substances derived from the blood may be separated from it, for it is allowed that the earthy matter of bones is as distinctly a secretion as when it is deposited on parts which in their healthy condition are free from it. The nutrition or *nourishment* of the different organs of the body depends as much upon the exercise of the function of absorption as upon secretion; that is to say, it is as necessary that the old be removed as that fresh materials be deposited; and since the term interstitial absorption has been applied to the removal of the textures, in like manner we apply the term interstitial secretion to the depositation of new matter in these textures; and by the term nutrition we understand the result of the action of both.

From the first rudimental state in the womb till life is extinguished in old age, the weight and bulk of the body is continually changing; its organs undergo alterations in consistence, colour, elasticity, and even chemical constitution. The materials which compose the body of the adult man did not enter into the construction of the infant; nor do the materials of the robust man continue to extreme old age. The matter which forms the body which we place in the grave did not constitute the same body a few years antecedently. We are constantly throwing off old particles and adopting new; and many of those which enter into the composition of our frame to-day will not belong to us to-morrow. We cannot even be placed in the same room with other individuals for any length of time without mutually interchanging particles with each other. The emanations from one body are absorbed and adopted by another: and in like manner, of those particles which are thrown off one person, some are taken up by another, and become a part of his constitution.

The rapidity with which these changes are effected depends on a great variety of causes: on age, constitution, the state of health, and the texture of the individual parts. In the earlier periods of life nutrition goes on rapidly, speedily producing a complete renewal of parts; but as life advances the changes occur more slowly. To fix the limits within which complete alteration is effected in every part is therefore impossible. With those who have attempted it, the period of seven years is a favourite one, very likely in part from some mysterious attachment to the number seven. The soft parts, and those organs in which depositation and absorption are carried on with great activity, will be completely renewed several times for once of those parts which are denser in their texture, and in which the circulation is more subdued. Sailors, soldiers, and several savage tribes, are in the habit of impressing the skin with figures, in which they trace and insert colouring matters, which remain during their lives; and by the use of the nitrate of silver the skin has been rendered permanently blue, which would appear to disprove the renewal of the skin; but it is possible that the absorbents refuse the colouring matter employed in tattooing; and as to the colour produced by the internal use of the nitrate of silver, it has frequently completely disappeared after having remained for some years.

CHAPTER VII.

NERVOUS SYSTEM.

Introductory Remarks—Hairy Scalp—Skull formed of separate Bones—Advantages of this Construction—Consists of two Plates—Advantages of—Membranes of the Brain, and the Purposes they serve—Divisions of the Brain—Presents one Continuous Surface, without the slightest trace of Division—Dr Spurzheim's Demonstration of—Enormous Quantity of Water collected in—Microscopic Observations of Bauer—Of Ehrenberg—Structure described—Evolution of the Nervous System in size and complexity, accompanied with Parallel Advances in the Higher Instincts and Sagacity—Development of the Brain in the Fœtus keeps pace with that of the System in general—Weight of the Brain in proportion to that of the Body—Size in proportion to the rest of the Nervous System—Brain the Seat of the Mind—Results of Experiments on—Spinal Marrow, its Structure and Development—Views and Experiments of Sir Charles Bell—Classification of the Nerves—Nerves of the Specific Senses—Announce the properties of External Bodies—Motiferous Nerves—Convey the Commands of the Will—Respiratory Nerves—Indicate the Instinctive Feelings, Passions, and Emotions of the Mind—Their Universal Distribution—Regular Double-rooted Nerves—One Root transmits the Mandates of the Will—The other communicates Impressions received—Ganglionic Nerves—Immediate Seat of Individual Vitality of the different Organs of the Body—Their General Connections—Universal Distribution—Four great Ganglionic Nervous Centres.

The nervous system, to which our attention is now to be directed, furnishes the material instrument of thought, the means by which we become acquainted with the external world around us, the channels by which the commands of the will, the impressions of instinct and of passion, are conveyed to the instruments by which they are displayed, and the cords of connection which associate the various organs of the body into one harmonious whole. Forming as it does the bond of union between the intellectual and physical conditions of the constitution of man, it is equally interesting and important whether we especially devote our attention to sciences which have for their consideration the one or other of these two states of human existence.

Neither the limits nor object of the present work permit us to enter upon the examination of many subjects of the utmost importance connected with the nervous system; others involve so much controversy and contrariety of opinion, that to embark in them we should be necessarily led far beyond the boundaries within which we at present wish to confine ourselves. In treating of this department of our subject, we shall therefore altogether avoid metaphysical disquisition, and as much as possible controverted points, but shall endeavour to give as clear and complete, at the same time as concise an account of the nervous system as we can, taking care to advert to the functions dependent upon it.

We shall consider this system under the following divisions, and in the following order: 1*st*, The brain, comprising the cerebrum, cerebellum, and medulla oblongata. 2*dly*, The spinal cord; and 3*dly*, The nerves. The last we shall classify under five orders:—1. Nerves of special sense. 2. Nerves of simple voluntary motion. 3. Nerves of respiratory or instinctive movements. 4. The regular or double-rooted nerves. And 5. The ganglionic nerves.

The Brain, constituting the most important organ in the whole body, and being, from the delicacy of its texture, incapable of resisting external influence, is carefully and admirably protected. The coverings of the brain are the scalp, the skull, and certain membranes.

The hair of the head, furnishing as it were a covering of felt, serves as a protection, by deadening blows, and preventing injury from pressure. Besides, being a bad conductor of heat, it preserves an uniformity of temperature; by favouring exhalation, it contributes to the same effect; and being impregnated with an oily matter from the sebaceous follicles, it is enabled to resist moisture.

The fat in the cells of the scalp is less liable to variation in quantity than in most other parts of the body, and never accumulates to any considerable extent.

Beneath the common integuments of the head there is situated a muscle extended by a broad tendinous sheath from the occiput to the forehead, hence called occipito-frontalis. By means of this muscle, some individuals are able to move the hairy scalp freely backwards and forwards, but in most persons its movements are limited. It elevates and wrinkles the skin of the forehead. Immediately investing the skull, there is a dense fibrous membrane, similar to the membranes covering other bones, here termed pericranium, upon which the vessels entering the bone are distributed.

The skull is divided by anatomists into the bones of the cranium and those of the face. Of the former there are eight, and of the latter fourteen. Nothing could more beautifully illustrate the principles and advantages of the arched form, than the construction of the skull, by which lightness and strength are combined. Where the bone is thin, it is so formed as rapidly to diffuse a blow in different directions. Sometimes the force thus diffused is concentrated again on the opposite side of the skull to that to which the blow was applied; but, proceeding from the concave instead of the convex surface of the arch, a piece is thus apt to be driven out. Where the bone is so situated as to be liable to a concentration of force, it is there increased in thickness and strength.

The skull is much more capable of resisting external force, from being composed of separate bones, and at their junctures a freer vascular communication exists between the external and internal surfaces. At birth, the bones of the cranium, at the upper part, are not even in contact with each other. When the head is compressed, they may be made to overlap, whereby birth is more easily accomplished, and subsequently they yield to the growth of the brain. When the brain arrives at its full size, the bones become more complètely united, and do not readily yield, and in advanced life their joinings or sutures, as they are called, are often entirely obliterated. The facility with which the sutures give way in childhood to pressure from within, is the reason why water can accumulate without proving immediately fatal. In such cases the head occasionally becomes enormously enlarged, so as to be capable of containing several pints of fluid; while in a more advanced period of life, the bones being more firmly united, such collections cannot take place, consequently the diseases in which fluids are effused become more rapidly fatal. Some of the bones at the sutures overlap each other like the scales of a fish; some are dove-tailed, the projections of the one being received into corresponding depressions of the other; some are inserted like the panels of a door, while others meet by plain edges. Every one of these instances may easily be shown to be the best possible, as adapted to the circumstances of each individual case. For example, the outer table of the skull is tough and fibrous, like a board of wood. Here dove-tailing is employed, but the inner table is brittle, requiring to be joined by even surfaces, like two pieces of glass, which method is accordingly adopted.

The skull is formed of two layers or tables, as they are termed, the outer of which is nourished by the pericranium, while the internal is supplied with blood by the vessels of the lining membrane. The two tables differ from each other in their density, as has just been stated; between them there is interposed a spongy substance termed diplöe, in which the bone is very cellular in its texture. This serves the same purpose as deadening in flooring, whereby concussions are lessened in their passage from the external to the internal table; the latter being much less capable of resisting their effects, the danger to the brain is in this way also much diminished.

The bones of the cranium are proportionally large, compared with those of the face, in infancy and childhood. But afterwards those of the face outstrip in their growth the bones of the cranium. The bones of the cranium, which are in connexion with those of the face, require therefore to increase proportionally in their growth, so as to keep pace with the face, and preserve the symmetry of the parts. This they do, however, only in their external table, the internal remaining to preserve the symmetry with the bones of the cranium. From this inequality of development spaces are left between the two tables, termed sinuses. In the forehead immediately under the eyebrows, there are two such, named frontal sinuses. It sometimes happens that the brain shrinks from disease: this occasionally occurs in idiocy, succeeding insanity. In such instances the internal table follows the diminished brain, when the distance between the two tables is increased, the intervening space being either filled with diplöe or remaining empty, forming sinuses. The skulls of the insane are thus frequently very thick. In the elephant the space between the two tables is in some parts to the extent of a foot, the size of the head of that animal giving no idea of the size of the brain, though it imparts to him an air of great sagacity.

Lining the internal table of the skull there is a firm dense membrane named *dura mater*, from the older anatomists considering it as the origin or mother of the hard firm membranes of the body, just as they held the delicate vascular web which is in immediate contact with the substance of the brain, to be the mother of the tender membranes, and called it the *pia mater*. Interposed between these two is the *arachnoid*, as fine and fragile as a spider's web, from which circumstance it derives its name. The dura mater is a strong fibrous membrane, serving as an internal periosteum. It adheres to the internal surface, and especially at the sutures, by means of the blood-vessels, which pass between it and the bone: at the base it still more firmly adheres, partly on account of sending processes through the holes at which the blood-vessels and nerves pass at certain parts. It is separated into two layers, the internal of which is doubled on itself, so as to form two remarkable processes, the one termed *falciform process*, from the resemblance of its shape to a sickle, the other, from being extended over the cerebellum, is called *tentorium cerebelli*. The falciform process is interposed between the two hemispheres of the brain, so that when we lie upon one side the hemisphere which is placed uppermost is prevented from pressing upon the lower one. In the same way the pressure of the cerebrum upon the cerebellum is obviated by the tentorium, which otherwise would have happened when the head is in the erect position. Between the layers of the dura mater are situated those sinuses to which we had occasion to refer when treating of the peculiarity of the circulation through the brain, wherein the blood is safely lodged without the risk of pressure on the susceptible cerebral contents. A tubular prolongation of the dura mater is extended along the vertebral canal, so as to serve as a protection to the spinal cord, but it does not come in contact with the bones of the canal.

The arachnoid membrane, as we have seen, belongs to the class of serous membrane, and is the most delicate of the order. It covers the internal surface of the dura mater, whence the latter is sometimes described as being fibro-serous: it is extended along the spinal cord, and reflected over the surface of the brain externally as well as internally.

The pia mater has a closer analogy to cellular membrane than to any other class: it is peculiarly distinguished by having the cerebral blood-vessels minutely subdivided upon it before they enter the substance of the brain itself: it is closely attached to the surface of the brain, following all its convolutions, entering into its cavities, and is prolonged down the spinal canal, investing the cord; it also affords a covering to the nerves, forming what is termed their *neurilema*, or immediate investment; so that in this way it extends to every part to which nerves are distributed, and thus constitutes one of the most extensive as well as important membranes in the body, intimately connected as it is with the paramount constituent of the animal organism, the nervous system.

Cerebrum or Brain proper.—The whole nervous system is double, or composed of two symmetrical halves, a right and a left; these have connexions established between them by transverse bands termed commissures, by which they are brought into accordance and co-operation with each other, and on which the individuality of the animal essentially depends. The two halves of the cerebrum are called hemispheres, each of which is divided by anatomists into three lobes, the anterior occupying the forehead, the middle placed by the temples, and towards the base of the skull, and the posterior situated at the back part of the head.

The nervous tissue is composed of two substances, differing in colour and consistence. The one is of a grey, or rather cineritious or pale ash colour, of a softer texture, and more abundantly supplied with blood. The other is white, of a firmer consistence. The former, from its colour, is called cineritious, or sometimes from its occupying the surface of the brain it is termed cortical; the latter, from being placed chiefly in the central parts of the brain, receives the name of medullary. Their relative position, however, is in several parts reversed, as in the spinal cord.

The surface of the cerebrum is divided into a great number of waving eminences termed convolutions, by which the surface is greatly extended. The convolutions are confined to the class of mammalia; but they are not found in the whole of this class, for the order of rodentia or gnawers, such as rats, mice, and squirrels, are destitute of them. Each convolution consists of a layer of cineritious matter on the surface, with a layer of medullary matter in the centre. Dr Spurzheim was the first to show that these convolutions may be unfolded so as to present one uniform surface of cineritious substance externally, with a corresponding extension of medullary matter beneath. They are occasionally unfolded in cases where a large quantity of water is collected within the brain.

On Dr Spurzheim's first visit to Edinburgh, we enjoyed the advantage of hearing his lucid demonstrations on the structure of the brain and nervous system, and of witnessing several of his private dissections. The account he gave of the manner in which the convolutions of the brain are occasionally unfolded, in cases of water in the head, excited in us great interest. Sometime afterwards a case fell under our own observation, which may be here adverted to, where we had an opportunity, under the most favourable circumstances, of observing the changes which had been effected from the accumulation of a large quantity of water in the ventricles of the brain.

A female child, about four months after birth, was noticed to have an unusually large head. Till the fourth year, however, it did not excite much attention, and the mental powers up to this period seemed to be developed in the ordinary degree. At this period, however, the head began rapidly to enlarge, and the mind became more and more obscured, till complete idiocy supervened, and continued till her death, which occurred in her twenty-second year. We had several opportunities of seeing her some years before her death. The head was too large to admit of being supported by the puny muscles of the neck; she therefore constantly lay on a pallet by the side of the fire. The body was small, and deformed. She appeared to have some slight glimmerings of mind, was readily amused, like a young child, with noise and brilliant objects, shewed some attachment to her parents, and for years kept rubbing a penny piece in her hands, which she would not for a moment part with day or night. When we first saw her it was reduced to the thinness of a wafer.

Twenty-four hours after her death, permission having been obtained to examine her body, the following measurements of the skull, on the removal of the scalp, were made :—From the great occipital hole, over the crown, to the space between the eyes, $24\frac{6}{8}$ inches; from one auditory passage over the crown to the other, $21\frac{6}{8}$ inches; circumference 29 inches. On carefully removing the skull-cap, and exposing the brain, the hemispheres appeared like a large bag filled with water. On the upper surface and sides no trace of convolution could be noticed, but they were not completely unfolded on the base. Upon puncturing the bag, ten pints and a quarter of water escaped; and on examining the interior it presented a vast dome, consisting of a thin layer of cineritious matter on the external surface, and a layer of medullary internally. The fibrous arrangement was beautifully displayed: the cerebral ganglions and tubercles lay at the base, of the usual size. The cerebral contents of the skull weighed two pounds eleven ounces.

The convolutions are more numerous and extensive in man than in any other animal. The depressions between them are also much deeper in him. If the convolutions of the human brain were all completely unfolded, a surface would be presented much more extensive than in any other animal. We may have some idea of the manner in which these convolutions are formed by taking two pieces of cloth of different colours, laying the one upon the other, and collecting them up in folds into a globular shape, so as rudely to represent the brain with its various convolutions. By this arrangement a much greater surface of cerebral matter is packed up in the space occupied by the brain than could have been effected in any other way. It is also to be remarked that there is not the slightest line of demarcation between one part of this extended surface and another: it is not like the skin, which varies in different situations, different as it is in appearance, and modified in structure when extended over the cheeks, the body, the limbs, the palms of the hands, and points of the fingers, while the surface of the brain presents one uniform unvaried continuous surface, without the smallest change of appearance in colour, consistence, or texture, however eagerly it may be sought after.

According to the estimate of Baron Haller, a fifth part of the whole blood of the body in man is sent to the brain. The vessels are first divided and subdivided into exceedingly minute tubes before they penetrate the substance of the nervous matter, and are more abundantly distributed upon the cineritious substance; so much so that when minutely injected that matter appears to be entirely composed of blood-vessels. Microscopic observations have shewn that the nervous matter is composed of globules. According to Mr. Bauer, the dimensions of these globules vary from $\frac{1}{4000}$ to $\frac{1}{2800}$ part of an inch in diameter; some few being $\frac{1}{2000}$, or, according to his measurement, of the same size with the globules of the blood, when divested of their coloured investment. With it he estimates the size of the blood globules as $\frac{1}{1700}$ part of an inch in diameter. We thus perceive that the nervous globules are much smaller than those of the blood. As a standard for comparison, it may be stated that the human hair varies from $\frac{1}{700}$ to $\frac{1}{300}$ part of an inch in diameter. These globules are disposed in rows like a string of beads, and it is this arrangement which gives to the nervous system its fibrous appearance. He noticed a transparent tenacious jelly-like semi-fluid matter. Besides this jelly-like fluid, there exudes a colourless aqueous fluid, which evaporates on exposure to the air. Of these three—namely, the globules, the elastic jelly, and the colourless watery fluid—the nervous matter essentially consists.

According to the observations of Professor Ehrenberg, the nervous system consists of the three following forms of organic structure. 1. Minute tubes resembling hollow strings of pearls, the pearls of which are not in contact, which gives them a knotted, jointed, or articulated appearance. They contain a tough transparent fluid, to which he restricts the name *nervous fluid.* These tubules run in straight parallel lines, giving the fibrous character to the medullary matter, converging from the convoluted surface of the brain towards the base. They sometimes cross each other, occasionally ramify, but are never seen to anastomose. They form the principal constituent of the brain, spinal cord, and of the optic, auditory, and olfactory nerves. Fig. 20 shews the appearance which this structure presents under the microscope.

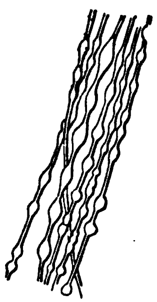

Fig. 20.

2. Simple cylindrical unjointed nervous tubes like the last, running parallel, and never anastomosing, about $\frac{1}{180}$ part of a line in thickness, and united into bundles, which again form larger bundles denominated the nervous cords. These bundles and cords, but not the individual tubes, are surrounded with a ligamentous vascular covering, or neurilema. The cylindrical tubes are larger than the jointed, and contain a viscid, whitish, less transparent matter, which he calls medullary. Ehrenberg has traced these medullary tubes along the motiferous nerves back to their emergence from the spinal marrow, and finds them to be continuous with the jointed—that is, the small jointed tubes containing the transparent liquid enlarge and become cylindrical tubes filled with medullary matter, forming the nerves, with the exception of the three special nerves of the senses of sight, hearing, and smell,

in which no such conversion takes place. The tubes, as well as the fluids, appear in this way gradually to pass into each other, and to form merely modifications of the same structure. Fig. 21 shews the appearance of these cylindrical tubes, some of which have been emptied of the jelly-like milk-coloured medullary fluid.

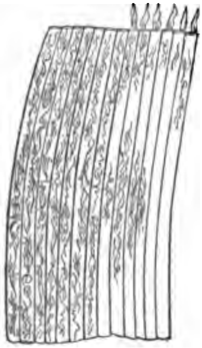

FIG. 21.

3. On the convoluted cineritious matter of the brain he observed a very fine-grained soft substance, in which here and there are scattered larger grains. The large grains are free, and consist of small granules, which appear to be connected in rows by means of slender threads to the very fine small grains of the substance. Fig. 22 represents the termination of the optic nerve in the retina of the eye, where the grains are seen of the size of $\frac{1}{300}$ part of an inch, lying upon the jointed tubes of which the retina is chiefly composed, their diameters being $\frac{1}{8000}$ part of an inch, and the nuclei of the grains are of the same size. The globules of nervous matter being arranged in rows, forming the tubular structure of Ehrenberg, produce the fibrous appearance presented in the brain, so that when we speak of the direction of the fibres, we in other words indicate the direction pursued by the rows of globules or jointed tubes.

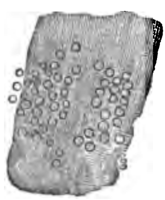

FIG. 22.

From the circumference of the brain the fibres proceed in two directions: the one set concentrate like rays towards the middle line, and meet their fellows of the opposite side, forming commissures whereby a consent and identity of action is established between the two sides of the brain. Between the two hemispheres there is situated the great commissure of the cerebrum, composed of parts formed of medullary matter, which are termed the *corpus callosum*, *septum lucidum*, and *fornix*. Towards the base there are two other medullary bands, named anterior and posterior commissures, and a fourth of cineritious substance is called the soft commissure. The medullary commissures constitute the converging fibres of Drs Gall and Spurzheim.

Another set of fibres like the last commence at the convolutions, and concentrate towards the base, where they form the crura of the cerebrum, and become continuous with the medulla oblongata and spinal cord. Gall and Spurzheim having traced these fibres from the spinal cord and crura upwards to the convolutions, have called them the diverging fibres, while the converging fibres of these authors constitute those which form the commissures.

Towards the centre and base of the cerebrum, the surface is inflected inwards, so as to form an intricate internal cavity, the several compartments of which are known under the name of *ventricles*. Of these there are the two *lateral*; the *third* and *fourth* are situated between the cerebellum and the medulla oblongata. They are all covered with pia mater and arachnoid, which are extended into them. They communicate with each other, and serve to increase the cerebral surface. The two lateral ventricles are the largest, and each contains a fold of the pia mater invested with arachnoid, in which there are numerous blood-vessels, chiefly veins, which form what is termed the *choroid plexus*. It is principally in the ventricles that collections of serous fluid take place in cases of water in the head. In the healthy condition of the brain they can scarcely be considered as cavities, but rather as means whereby the surface of the brain is still further extended. Like the external surface, it is constantly bedewed with moisture exhaled from the serous membrane covering it, and which only accumulates in quantities when the balance between secretion and absorption is subverted.

Along the floor of the lateral ventricles there are situated two swellings, sometimes named the anterior cerebral ganglions. From streaks of white matter being seen passing through the cineritious substance of which they are principally composed, they are more commonly known under the name of the striated bodies, and are connected with each other by the anterior commissure. Immediately behind them are placed two other swellings, or posterior cerebral ganglions, which, from the circumstance of the optic nerves resting upon them for some length of their course, are termed the *optic thalami*. They are united behind by the posterior commissure, and in the middle by a quantity of grey matter forming the soft commissure.

Still further back, just before the prolongations from the cerebrum and cerebellum unite to form the medulla oblongata, we have four rounded tubercles or ganglions, disposed in pairs, suggesting the idea of twins: hence they are named the four twins, or *tubercula quadrigemina.*

The pineal gland is placed between the anterior tubercles and the posterior cerebral ganglions, with the latter of which it is connected by bands of medullary fibres.

We have thus four pairs of ganglions near to the base of the brain, the anterior of which is the largest, each pair becoming smaller as we count backwards, and in the middle of them the pineal gland is placed in a situation which once gained for it the pre-eminence of being considered the especial seat of the soul.

The Cerebellum, or little brain, is about one-eighth of the size of the cerebrum. It is situated at the back part of the head, and divided into two lateral lobes. It is composed of cineritious and medullary matter like that of the cerebrum. Instead of waving convolutions, its surface presents from sixty to seventy nearly horizontal plaits, with smaller ones interposed between them, by which arrangement its surface is vastly extended.

The fibres of the cerebellum, like those of the cerebrum, proceed in two sets. The one set pass obliquely downwards, and become continuous with the medulla oblongata and spinal cord: the other incline forwards, and form what is called the *pons* or bridge of Varolius, bearing the same relation to the cerebellum that the great commissure does to the cerebrum. The former constitute the diverging, and the latter the converging fibres of the cerebellum, according to Gall and Spurzheim. On each side a fasciculus or bundle of medullary fibres also proceed upwards to the posterior pair of the tubercula quadrigemina, in which they terminate. They are united by a semitransparent medullary web, which serves as a commissure, though it gets the name of a valve.

If a vertical section be made of one of the lobes of the cerebellum, a peculiar appearance is presented, resembling the stem and branches of a tree, and therefore called *arbor vitæ.*

From the above description it will appear that the cerebrum and cerebellum are each composed of two sets of fibres, which, commencing at the surface, run in two directions, the one proceeding to become continuous with the columns of the spinal cord, the other running towards the middle line to meet with their fellows of the opposite side, so as to establish an unity and sympathy of action between the right and the left.

The Medulla Oblongata may be considered as the common centre of the cerebro-spinal portion of the nervous system, or where the influences of intellect, passion, instinct, sensation, and motion meet and associate, and as that part on which life more immediately depends. Those parts of the nervous system with which intellect, passion, and instinct are especially connected, may be destroyed without the immediate extinction of life. The nerves on which sensation or voluntary and instinctive motion are dependent may be cut by way of experiment, or rendered wholly incapable of performing their function by disease; nevertheless death does not necessarily follow, but the instant that the medulla oblongata is touched, in the same moment life is extinguished. For this reason sportsmen sometimes terminate the sufferings of their game by introducing an instrument so as to destroy this part; and in some countries it is the practice with butchers to spine, or pith as it is called, the cattle which they kill. It may also be observed, that many animals of prey, especially birds, strike their victims on the back of the head, or at the top of the neck, so as instantly to deprive them of vitality.

The medulla oblongata is formed of six columns, or three pairs. The two anterior are continuous with fibres both from the cerebrum and cerebellum. Those from the surface of the crura of the cerebrum pass under the pons, and descend along the whole length of the spinal cord. Immediately under the pons they are of a pyramidal shape, and there known by the name of the pyramidal bodies or eminences. About an inch below the pons, some of the fibres of the pyramids decussate; those of the right side crossing to the left, and those of the left to the right, and this they do either in one bundle or in several divisions, differing in this respect in different individuals. This decussation of the pyramidal bodies enables us to explain how injuries of the brain on one side are followed by loss of power or paralysis of the opposite side of the body. The posterior pair of columns are termed the posterior pyramids or restiform bodies. They are continuous with the diverging fibres of the cerebellum, and with others from the cerebrum, and are prolonged downwards along the spinal cord.

Between the anterior and posterior pyramids, two middle or lateral bodies are placed. From their resemblance to the fruit of the olive, they are called the olivary. Fibres proceeding from them may be traced upwards under the pons to the crura and cerebral hemispheres, and also downwards along the side of the spinal cord, but very faintly on the cord.

A narrow line of white matter lies upon the olivary bodies, between them and the posterior pyramids. This line is most distinct at the upper part of the medulla oblongata. The fibres of which it is composed may be traced upwards to the inferior of the tubercles, but not to the hemispheres. Downwards, they terminate opposite to the fourth vertebra of the neck. From this track the nerves of respiratory or instinctive motion have their origin. It has been already mentioned, that the pons is formed by the converging fibres of the cerebellum, which cross the sides of the medulla oblongata, and meet their fellows of the opposite side, so as to form the commissure of the cerebellum.

Nothing can be more striking than the difference between the remarkable simplicity of the structure of the nervous system, and the multiplicity and intricacy of the functions to which it is subservient. Nevertheless, the condition in which it is found in the various classes and tribes of animals, as well as its successive evolution in the human subject, from its primary rudimental state to its complete development, shew us that some portions perform much higher functions in the animal economy than others. Just as we find gradual and almost imperceptible steps of progressive improvement, from the most simply organized zoophyte up to man, in the mechanism of the organism, correspondent with the scope, variety, and extent of the function exercised, so do we find different parts of the nervous system gradually unfolded, coincident with the development and manifestation of the organs and faculties.

In zoophytes, the nervous globules are disseminated through the general mass of which their bodies consist, without being concentrated into any given point. In the more perfect invertebrate animals, as the structure becomes more complicated, the nervous matter assumes a distinct arrangement, so as to form one or more swellings or ganglions connected with each other by intermediate nervous threads, the number of the ganglions, and the intricay of the communications corresponding with the development of the organs. As we ascend in the scale of animal existence, and examine the lowest class of vertebrated animals, fish, we find superadded to the ganglionic system, a spinal marrow, with nerves of voluntary motion and sensation, of instinctive movement, of peculiar sense; but the brain is merely in a rudimentary state. As we proceed through the other three vertebrated classes, reptiles, birds, and mammalia, we find a successive evolution in the size and complexity, especially of the brain, and nerves more immediately connected with it, and observe that these increments are accompanied with parallel advances in the manifestation of the higher instincts, sagacity and intelligence, till we reach man, the most sagacious and most intelligent of all animals, and who feels himself a moral and responsible creature.

The fœtus is found to pass through several successive stages of organization, or it undergoes a variety of metamorphoses, commencing with the more simple forms in the structure of the organs connected with the different functions, becoming more elaborate and complicated at the different periods of its growth and development. Of the nervous system, the ganglionic portion is that which is first established, to which the spinal cord, and nerves in connexion with it, next succeed, and lastly, the brain; the hemispheres being the last to be completely unfolded, for even at birth the convolutions are scarcely established. The medullary matter, at least so far as the brain is concerned, takes precedence of the cineritious.

The weight of the brain, in proportion to that of the rest of the body, varies in different animals, as will be seen from the following table of instances selected from Blumenbach's Comparative Anatomy:—

Man .... $\frac{1}{22}$ $\frac{1}{25}$ $\frac{1}{30}$ $\frac{1}{35}$

Orang Outangs.

Gibbon .... $\frac{1}{48}$

Sapajous (American Apes.)

Saïmiri .... $\frac{1}{22}$

Saï .... $\frac{1}{25}$

Ouïstiti .... $\frac{1}{28}$

Coaïta .... $\frac{1}{41}$

African and Indian Apes.

Malbrouk .... $\frac{1}{24}$

The Monk Ape .... $\frac{1}{44}$

Other Mammalia.

Dog .... $\frac{1}{47}$ $\frac{1}{50}$ $\frac{1}{134}$ $\frac{1}{161}$ $\frac{1}{305}$

Fox .... $\frac{1}{205}$

Cat .... $\frac{1}{82}$ $\frac{1}{94}$ $\frac{1}{156}$

Beaver .... $\frac{1}{290}$

Hare .... $\frac{1}{228}$

Rat .... $\frac{1}{76}$

Mouse .... $\frac{1}{43}$

Elephant .... $\frac{1}{500}$

Wild boar .... $\frac{1}{672}$

Chinese hog .... $\frac{1}{451}$

Roebuck .... $\frac{1}{94}$

Stag .... $\frac{1}{290}$

Ox .... $\frac{1}{860}$

Calf .... $\frac{1}{219}$

Horse .... $\frac{1}{400}$

Ass .... $\frac{1}{254}$

Porpoise .... $\frac{1}{93}$

Dolphin .... $\frac{1}{25}$ $\frac{1}{36}$ $\frac{1}{66}$ $\frac{1}{102}$

Common whale .... $\frac{1}{3000}$

Birds.

Canary bird .... $\frac{1}{14}$

Goose .... $\frac{1}{360}$

Reptiles.

Frog	$\frac{1}{172}$
Turtle	$\frac{1}{5688}$
Fishes.	
Carp	$\frac{1}{560}$
Shark	$\frac{1}{2496}$
Tunny	$\frac{1}{13450}$

It will be perceived from the inspection of the above table that no inference of the slightest importance can be deduced from the weight of the brain compared with that of the rest of the body: that the proportion varies exceedingly in different individuals of the same species, and indeed in the same individual at different times, for the brain does not alter with the increase and diminution of weight to which the body is so liable in various conditions of health and disease. Thus an animal may become enormously fat when the weight of the brain will bear a smaller, or if emaciated, a larger relative weight to the whole bulk of the body.

When we compare the size of the brain with that of the spinal marrow and nerves arising from it, we find that the proportion they bear to each other has a connection with the rank the animal may hold in the scale of intelligence, and also with its tenacity of life. Of all animals the brain of man has the greatest development, not only in the size, but also in the intricacy of the structure and extent of its surface in proportion to the spinal marrow and nerves; while in animals lower in the scale, as reptiles and fishes, the brain presents merely a delicate anterior termination of the spinal cord, not much larger in its diameter, and differing from the rest of the cord chiefly in presenting a more complicated organization, in which we have the more important parts of the brain exhibited in a rudimental state; and in being connected with a greater variety of nerves, both as to their number, and the functions with which they are associated. In these animals the instincts are limited, and the displays of sagacity extremely obscure, while they possess great tenacity of life; and their different systems of organs seem less intimately connected and more independent of each other. Frogs still continue to jump about for some time after their heart has been torn out; and the heart of the shark will palpitate for several hours after it has been removed from the body. In one instance we saw the heart of a large skate distinctly display contractions on being pricked with a needle thirty hours after removal. Turtles have continued to live for months after the whole brain has been scooped out.

In some of the lower tribes of invertebrate animals, the independent existence of the different parts is still more strikingly displayed; for on dividing their bodies, provided each piece retains a nervous ganglion, it will become a separate individual, adequate to the exercise of all the functions performed by the entire animal, and reproducing at each extremity new portions, which likewise become endowed with distinct vitality; and when we descend to zoophytes, we find that on cutting them into shreds, however minute or irregular, each piece retains life and continues to grow, division forming in them one of the means of rapid multiplication.

Numerous experiments and observations on different animals, and on man in different conditions, tend to establish the conclusion that the cerebrum is entitled to be considered as the special organ through which are displayed the passions, the emotions, the intellectual powers, and the moral affections of the mind; that it is the throne from which the behests of the will are issued forth to the various parts of the body under its control, and to which the various impressions received by the organs of sense are finally communicated.

From the earliest times the brain has been generally understood as the established seat of the mind. Thus, according to ancient mythology, Minerva, the goddess of wisdom, sprang ready armed from the head of Jupiter; and the "king of gods and men" is uniformly represented with an enormous head; while in athletes and heroes gifted with muscular strength, the head is very small in proportion to the rest of the body. It is certainly reasonable to suppose that the size, and the more or less elaborate construction of that organ from which the conceptions of the mind are issued, and through which the impressions from external agencies are appreciated, should exhibit proportional relations to the instinct, sagacity, and intelligence of the animal; so we find comparative anatomy, as well as the gradual evolution of the nervous system in the fœtus, support this view.

Notwithstanding the innumerable observations and experiments which have so long engaged the attention of the most distinguished physiologists of past times, and more especially of the present age, the precise share which the different parts of the brain exercise in the various functions with which it is confessedly connected, has been by no means ascertained. It is, however, sufficiently established by experiment, that although the cerebrum, either conjointly with, or independently of, the cerebellum, be the instrument which takes cognizance of sensation, and the source from which the motives spring which call forth voluntary and instinctive motions, yet it may be sliced off in successive layers without the animal showing the slightest marks of suffering, and that neither indication of pain nor excitement of movement occur till the turbercles are reached, when violent convulsive movements are produced, accompanied with expressions of intense suffering. The hemispheres, the commissures, the anterior and posterior cerebral ganglions, may be thus removed layer after layer, without exciting pain or motion. The senses, however, no longer produce perception. Memory, intelligence, and judgment are abolished, and the animal appears to be reduced to a kind of automaton, deprived of desires, apprehensions, and judgment.

Similar sections have been performed on the cerebellum, with results shewing that it is equally insensible and incapable of exciting motion as the cerebrum; that when it is extirpated, feeling, volition, and perception are retained, while the animal is no longer capable of regulating its movements; if it attempts to walk, it staggers about without the power of commanding the necessary co-operation of the muscles, or infusing the precise degree of energy necessary for the due performance of the task. The distinguished experimenter, M. Fleurens, observes, "In depriving the animal of the cerebrum, it was thrown into a state resembling sleep; in removing the cerebellum, it was brought to a state resembling intoxication."

Through the medulla oblongata the influence of the cerebrum and cerebellum is transmitted to the nerves, which obey the will; it serves also as a channel for conveying to those parts the impressions received by the nerves of sense and general sensation. Besides these offices it would appear that it is endowed with the power of instituting motions, and that it forms the general centre and great bond of connexion between the different portions of the nervous system.

Spinal Cord.—Between the medulla oblongata and spinal cord there is no distinct line of demarcation. They are therefore held by several anatomists as one organ, and as such described. The medulla oblongata, however, consisting of six columns, giving rise to several nerves of distinct function, being the point at which excitement to motion commences, and sensation terminates, and possessing the power of originating motion in itself, seems from these circumstances entitled to a separate consideration. Mere continuity of structure and identity of texture might equally be brought forward as a reason for regarding the cerebrum and cerebellum also as merely portions of the same organ, as indeed in many respects they are.

For these reasons it appears more advantageous to separate the spinal cord from the medulla oblongata, though it is by no means easy to fix upon a point at which the one terminates and the other commences, they slide so imperceptibly into each other. The old anatomical line of separation may therefore be adopted, that is, where the medulla escapes from the foramen magnum, or great hole in the base of the skull.

Leaving the foramen magnum, the spinal cord proceeds down the canal of the vertebræ, till it reaches the first or second vertebra of the loins, where it generally terminates in a spindle-shaped extremity. In the fœtus it is prolonged through the whole extent of the canal, as it is in animals with a tail. In the earlier periods of fœtal life, the human subject is furnished with a caudal appendage, which gradually disappears as the system becomes unfolded, though some monsters have been born with a tail. Indeed a great number of monstrosities arise from the circumstance of the evolution of the organ affected having been arrested in some of the stages through which it passes, from its first rudimentary state to complete development. The ascent of the spinal cord in the canal is to be attributed partly to the extension of the lower limbs, and enlargement of the pelvis, so that it is as much merely apparent as real.

Besides the strong and admirably constructed case of bone in which the cord is lodged, it is surrounded by a tubular prolongation of the dura mater, which does not adhere immediately to the bone as it does within the skull. It is also supplied with extensions of the arachnoid and pia mater, which closely invest it. Between the arachnoid and pia mater there is a quantity of thin serous fluid, varying from two to six ounces. The cord is thus surrounded by a fluid medium, and is kept steady in this fluid by little ties or stays, which stretch from the dura to the pia mater. They are attached along the sides of the cord, between the anterior and posterior roots of the nerves, having the appearance of the teeth of a saw, and are therefore termed the dentated processes. A similar fluid to that in the canal is effused between the arachnoid and pia mater throughout their whole extent, over the internal and external surfaces of the brain. Besides imparting a certain degree of support by its pressure, it is admirably adapted to obviate the effects of concussion, so as to prevent injuries from jars which these organs are so impatient of, and by which they are so liable to be injured.

The general form of the spinal cord is cylindrical, though somewhat greater in its transverse diameter, so that it presents a flattened appearance. It is not uniform in thickness throughout its whole extent, but is enlarged at the lower part of the neck, where the nerves of the arms have their origin, and again at the lower part of the back, from whence spring the nerves of the legs. The substance of which it is composed is similar to that of the brain, consisting of cineritious and medullary matter, the latter being disposed in a thin layer upon the surface, while the former constitutes its central nucleus, so that we have here the relative position of the two reversed from what occurs in the cerebrum and cerebellum. This disposition, however, also obtains in the medulla oblongata, and in the central parts of the cerebrum and cerebellum.

The cord is divided into two lateral halves by a groove in front, and a similar groove behind. On each side there are also two lateral grooves faintly marked, from which the anterior and posterior nerves have their origin. Each lateral half is composed of two columns, so that the cord consists of four columns; from the two anterior the nerves of motion spring, and from the two posterior those of sensation.

Of no part of the nervous system has the function been more satisfactorily determined. For the discovery and complete establishment of this important truth, as well as for a more philosophical arrangement of the nerves in general, we are indebted to Sir Charles

Bell. The inextricable confusion in which the nervous system was involved, as taught by the most distinguished teachers, from which the genius of Bell has done so much to emancipate us, must be within the recollection of many; and although the structure which he has erected may not be complete in all its details, yet he has laid a firm foundation, and pointed out the way by which we may hope ultimately to arrive at a more just appreciation of this most interesting and most mysterious portion of our material constitution.

Thirty pairs of nerves spring from the spinal marrow; eight from the region of the neck, twelve from that of the back, five from the loins, and five from the pelvis. All these nerves arise by two roots, the one root from the anterior, and the other from the posterior column. The fibres from the posterior root swell into a ganglion before they unite with the anterior, in constituting the nerves which are distributed on the parts under the control of the will, and from which common sensation is derived. Sir Charles Bell ascertained, by laying open the spinal canal in a living animal, and dividing the posterior roots of the nerves, that the parts to which they are distributed are deprived entirely of feeling. The limb may be cut, pricked, or lacerated in any way, without the animal shewing the slightest indication of suffering: at the same time it retains the power of motion. In another experiment, he first stunned the animal, then exposed the spinal marrow, and pricked the posterior roots, without the slightest indication of irritation in the muscles with which they were connected being induced. But on grasping the anterior roots with the forceps, contraction of the muscles supplied by the nerve accompanied each touch of the instrument.

These experiments have been repeated by M. Magendie, and others, and varied in different ways, completely establishing the fact, that the anterior roots are subservient to motion, and the posterior to sensation; that one or other of these functions may be destroyed at pleasure, by cutting the roots with which either is immediately connected, and that on dividing the two roots, complete paralysis, both as to motion and sensation, ensues. One of Magendie's experiments is interesting. It is well known that the introduction of nux vomica into the animal economy produces violent spasmodic contraction, tremors, and rigidity of the muscles. This property was made available as a test of the distinct function of the two series of nervous roots. It was found that while all the muscles whose nerves remained entire were thrown into a state of the greatest agitation, those supplied with nerves, the anterior roots of which had been divided, remained relaxed and unaffected.

This discovery of the separate office performed by each set of fibres, explains what sometimes happens in disease, where a part of the body is deprived of motion, retaining sensation; or, conversely, sensation may be abolished, while motion remains, complete paralysis occurring where both roots are involved.

From the statements now made, it will appear that the impressions upon the surface of the body, and on all those parts endowed with common feeling, are conveyed by a peculiar set of nerves connected with the posterior columns, which serve as conductors upwards to the brain; that through perception exercised by the brain, these impressions are taken cognizance of, and the mind is enabled to appreciate them. If the result of the mental determination is such as to require the exercise of muscular action, the command is transmitted along the anterior column to the motific nerve, distributed to the muscle required to be employed, and instantly the muscle obeys. We have thus two streams of nervous influence: by the one intelligence is announced to the mind; by the other the purposes and resolutions of the will are communicated to the muscles necessary to carry these into effect. The circuitous course forms no objection, since we know, for example, that the galvanic shock is transmitted from one extremity to another of a wire miles in length without the smallest perceptible interval of time. The velocity of light affords another instance of rapid transmission, for astronomers have shewn that light reaches us from the sun in eight minutes and a quarter, or at the rate of 192,500 miles in a second of time; or we may say its velocity is such that it would traverse a space equal to eight times the circumference of the earth while the pulse makes a single beat. So the impression may be made at the point of the finger, the sensation communicated to the mind, the resolution formed, the command issued, transmitted and complied with, in an instant of time, so as to appear merely as one act, though in reality consisting of a succession of several.

If the chain of connection be interrupted, no command can be conveyed in the one direction, nor sensation in the other. Thus, when a double-rooted nerve is divided, the control of the will over the muscles on which it is ramified is lost; but by irritating the extremity of the divided nerve next to the muscles, the communication being unbroken, they are thrown into action. Again, when the limb is pricked or lacerated beyond the division, no sensation is experienced; but if the cut extremity nearest the brain be irritated, then is the pain felt, there being no interruption between the point of injury and the seat of perception. Thus we find that individuals who have had their limbs amputated frequently complain of pain as it were in the fingers or toes, of which they may have been deprived for years, because the stumps of the nerves that formerly supplied the amputated parts are affected.

The double-rooted nerves constitute an order, the function of which appears to be fully ascertained. Their distribution seems more uniform than that of some others: hence they have been called the regular or symmetrical. They all arise from the spinal cord. One pair of nerves from the skull, distributed to the face and other parts, resembles them in its double origin, in the anterior root swelling into a ganglion, and in its twofold function of sensation and motion. According to the numerical names which have been given to the cranial or those nerves which pass out of the skull, it is the fifth, so that, including this nerve, we have thirty-one pairs of regular nerves.

The nerves contributing to the senses of sight, hearing, and smell, are so obviously essential to the respective functions with which they are connected, that there can be no question as to the propriety of classifying them as a distinct order. Their numerical names are the first, second, and soft portion of the seventh.

There remain for consideration other cranial nerves, having only a single origin. Three of them arise from the anterior columns of the medulla oblongata, one pair springing from above, the other two from below the pons. These three pairs have consequently an origin corresponding with the anterior roots of the regular nerves, and like them contribute exclusively to motion. They are the third, sixth, and ninth.

Besides these three we have five pairs also taking their rise by single roots from the same line or tract. This tract is different from that to which the motiferous nerves are attached. It forms a slip of fibres, lying between the middle and posterior columns of the medulla oblongata, and may be traced downwards till it becomes gradually lost opposite the fourth vertebra of the neck; it is continued under the pons upwards to the inferior tubercle of its own side. The nerves proceeding from this tract, form an order to which Sir Charles Bell has applied the terms respiratory, or irregular. They constitute a division of his classification which is the least satisfactorily established, has excited the greatest controversy, and called forth the keenest opposition to the views he has taken. The names he has chosen seem likewise unfortunate, requiring an explanation of the sense in which they are applied. We need not, however, here enter upon these controversies, for although they may not deserve altogether to be considered as a distinct order of nerves, in so far as their function is essentially concerned, still their mode of origin, their manner of distribution, their character in different classes of animals, and their especial connexions with instinctive motions, all seem to entitle them to a separate examination. They comprehend the fourth dense portion of the seventh and eighth cranial nerves, and two from the neck, the phrenic and external respiratory.

The following is the arrangement we shall adopt in treating of the nerves: *First*, nerves of special sense, including the first, second, and soft portion of the seventh. *Second*, Motific nerves, the third, sixth, and ninth. *Third*, The respiratory, the fourth dense portion of the seventh, eighth, phrenic and external respiratory. *Fourth*, The regular nerves, comprising the fifth, cranial, and the thirty spinal nerves; and, *lastly*, we shall conclude with an account of the ganglionic nerves.

First Order. *Nerves of Specific Sense.*—The nerves of this order are, according to Ehrenberg, composed of jointed tubules like the substance of the brain and spinal cord. They are incapable of transmitting to the mind any other impression than such as belong to the respective senses with which they are connected. Thus, the olfactory can communicate only ideas of odours, the optic of colours, the auditory of vibrations, by whatever kind of stimulants they are excited. Electricity applied to the eye excites the impression of vivid light; to the nose, a peculiar odour; to the ear, sound. In the same way mechanical irritants produce on these nerves only appropriate impressions. When the expansion of the optic nerves is pierced by the needle of the surgeon, a flash of light is perceived. A blow produces the same effect, and the eyes are said to strike fire. Pressure upon the ball of the eye causes the appearance of a beautiful zone of light: not that light in any of these instances is produced, but because the optic nerve being irritated, announces to the mind its being affected in the only manner of which it is capable. These nerves are all connected with an apparatus admirably constructed for their individual functions, as we shall have occasion to shew. As they transmit their impressions from the organs to the seat of perception, they may be said to have their origin at the extremity unfolded in the organ, and their termination in the brain. For the sake of uniformity, however, it is as well to follow the general practice of considering the cerebral extremity as the origin, and the organic as the termination.

First, or Olfactory—the latter term being applied from their office. They are the softest nerves in the body, and are more closely connected with the hemispheres of the brain than any other. They are composed of three sets of fibres, two of them of medullary, and the third of cineritious matter. They may be traced backward to the anterior cerebral ganglions, and are seen lying under the anterior lobes of the brain. Proceeding forward, they swell into a bulb, from which numerous fibres issue, and pass into the nose through a plate of one of the bones of the skull. This plate is perforated by so many holes for the transmission of the twigs of the nerve, that it has the appearance of a sieve, a circumstance from which the bone obtains the name of ethmoid.

The olfactory nerve is ultimately distributed upon the lining membrane of the nose with which it is inextricably incorporated: it terminates upon the surface, and is merely defended by a layer of mucus, thus becoming the most exposed nerve in the body, for it is necessary that it should reach the surface, in order to come in contact with the vapours inhaled by the nostrils. The olfactory nerves are very large in some animals, particularly in ruminants, in which they are tubular. On the other hand, they are wanting in the whale tribe, which, if susceptible of odorous emanations, must therefore become cognizant of them through the medium of other nerves than these; and probably the fifth pair may perform to a certain extent this duty, as it seems in several tribes to be capable of fulfilling vicariously the office of other nerves. In fishes the bulb of the olfactory is placed immediately under the cup-like nostril. From the bulb the nerve runs backwards along a canal filled with transparent fluid, enters the skull, and joins the brain. In the cod-fish it tapers as it proceeds backwards, and terminates in the brain in a minute pencil of fibres.

The Second, or Optic, are the largest of the cerebral nerves, with perhaps the exception of the fifth. They can be traced as far back as the tubercles, and therefore arise from the upper part of the medulla oblongata. They pass along the base of the brain, and before they enter the orbits, unite with each other.

This commissure of the optic nerves has attracted a good deal of attention, and been the cause of considerable discrepancy of opinion. Some have held that they merely come in contact, others that they completely decussate, and a third party contend for semi-decussation—that is, they allege that one-half of the right optic nerve, for example, crosses to the opposite side, and joins a half of the left nerve to proceed to the left eye. The complete decussation without union which occurs in fishes supports the view of total crossing; so also in some experiments where the eye on one side has been destroyed, and time afforded for an alteration in the nerve to be effected, it has been found changed on the same side as far back as the junction, but on the opposite side beyond. Similar observations have been made in the human subject, where one eye has been lost. On the other hand, the destruction has been found to affect the optic nerve of the same side throughout its whole extent. It would appear from careful dissection that semi-decussation is what actually takes place; nor are the facts just stated inconsistent with it.

Each eye, therefore, receives its optic nerve from both sides of the brain—the right supplying the right side of both eyes, as the left does its corresponding side of both.

The optic nerve, on entering the orbit, proceeds forward to the ball of the eye, and penetrates the coats of that organ a little towards the nasal side, and in the centre; it then expands into a very delicate web or nervous network called the retina, which serves as a screen for the reception of the image falling upon it.

The Auditory, for some extent in its course, runs along with another nerve, the two together being known as the *seventh*, of which the auditory forms the soft portion, or *portio mollis*. It arises in the bottom of the fourth ventricle from the posterior columns of the medulla oblongata. Coming in contact with the *portio dura*, they proceed together to the internal auditory passage, which they enter. Within this passage the portio mollis divides into a great many minute branches, which are distributed to the several compartments of the labyrinth of the ear, where their extremities float in the water contained in that cavity, from which they receive vibrations productive of the impressions of sound.

SECOND ORDER. *Motiferous Nerves.*—In this order we have three nerves, characterized by their origins from the anterior columns, in the same line with each other, a line which corresponds with that from which spring the motiferous roots of the regular nerves, with which they agree in function. The separation of the fibrils of motion from those of sensation in this instance takes place however only at the cerebral extremities, for they are associated together at their further extremities. The greater portion of the fifth pair of nerves we shall find is sensiferous, and distributed to the parts on which the nerves of this order are ramified, thereby imparting to them sensation. The third, sixth, and ninth, with the fifth, may consequently be considered, in a physiological point of view, as analogous to one of the double-rooted nerves from the spinal marrow, and even others belonging to the respiratory order may likewise be included.

The Third Pair spring from the crura of the cerebrum above the pons. They may be traced into the substance of the anterior columns, where they are found to be connected with the grey substance of their centre. From their origin they pass forward to a hole in the bottom of the orbit, through which they enter that cavity, and supply four of the six muscles which move the eye, and likewise the muscle which raises the upper eyelid. Besides communicating to these muscles the commands of the will, a small twig of this nerve is joined by another from the fifth pair. Previous to the union the branch of the fifth swells into a small ganglion, from its shape named lenticular; so that we here observe the general law kept up of the formation of a ganglion in the sensific nerve before it becomes intimately associated with the filaments of motion. These twigs penetrate the coats of the eye, to which they impart sensibility. Being chiefly expended upon the iris, they become connected with its movements.

The Sixth Pair arise from the pyramidal bodies close to the pons. They soon pierce the dura mater, carrying along with them a tubular prolongation of that membrane. In their course they mount over a sharp ridge of the temporal bone; and run through one of the venous sinuses, named cavernous, from the blood of which they are separated by the lining membrane. Here communications are established between it and the great ganglionic nerve. It enters the orbit, and is entirely expended upon the muscle which turns the eye towards the temple. The length, of course, between the dura mater and the bone, and its passage over the sharp ridge of the temporal is probably the reason why this nerve is more liable to injury from concussion than any of the others; for we find that blows or falls are sometimes followed by no further mischief than the paralysis of the abductor muscle of the eye, whereby its antagonist keeps the eye permanently turned inwards to the nose, rendering the eye nearly useless, as its motions cannot properly be brought parallel with those of its fellow.

The Ninth Pair take their origin from the lower part of the pyramidal bodies. They pass through holes of the occipital bone. They proceed forward towards the angle of the jaw, where there is given off from each a branch which passes downwards in the neck to supply some of the superficial muscles anteriorly. The trunk of the nerve runs from the angle of the jaw, by the side of the hyoid bone of the tongue, and becomes ultimately distributed upon the muscles between the lower jaw, hyoid bone, and tongue, the motions of which it regulates.

THIRD ORDER. *Respiratory Nerves.*—It has been already stated, that there exists a greater discrepancy of opinion with respect to this than any of the other divisions of the nerves. We shall postpone our general remarks upon the order till we have had under review their course, distribution, and the functions of the parts on which they are expended, whereby the observations which may be submitted will be better understood, and the reasons which induce us to agree in some measure with those who hold them as entitled to be considered as a distinct class, directly connected with the expression of the sympathetic motions, and those which contribute to the expression of the passions and emotions of the mind, will be more readily appreciated. They arise from the same tract, and in the same line, with the exception of the fourth pair, which spring from below the inferior tubercles, from the valvular commissure crossing the fourth ventricle. This distinct origin is, however, more apparent than real, for the fibres from which the fourth originate, are continuous with the respiratory tract. The nerves belonging to this order are the fourth, the portio dura of the seventh, from its distribution on the face named facial, the eighth, consisting of the divisions, the phrenic, and the external respiratory.

Fourth Pair.—These nerves are the smallest of the cerebral, and arise by several minute filaments from the valvular commissure, close to the inferior tubercles. They run forwards, and enter the orbit at the same passage with the third and sixth, to be expended upon a single muscle of the eye, named the superior oblique, and communicating with the fifth. This muscle is curious in its construction, and interesting in the motions which it produces. It arises from the bottom of the orbit, lies along the roof of that cavity till it comes close to its brim, where it terminates in a small tendon, which passes through a loop or pulley, then proceeds backwards, and towards the temple. Its passage through this pulley changes the direction of its action, so that it carries the eye forward, and rolls it inwards to the nose, thereby giving to the eye a peculiar expression, as in ogling. As the eyes of lovers are said frequently to take this expression, the nerve has long been known under the name of the amatory. It is not merely, however, under the passion of love that this nerve declares, through the superior oblique, the sentiments of the mind, but it also becomes affected under other emotions and feelings; and hence it is called the pathetic nerve.

Whenever the will ceases to control the movements of the eye, that organ comes under the action of the superior oblique. When the mind is occupied and absorbed by emotion, we see the eye rolled by it; therefore painters give this position to the eye when they wish to depict intense mental feeling, such as deep devotion. Where the eyes are of unequal power, the person so affected habitually employs the stronger, leaving its weaker fellow to the action of the superior oblique, and squinting is the consequence. So accustomed are we to associate with this position mental feeling in the individual in whom it takes place, that squinting eyes are frequently supposed to express sentiments which may be far from being entertained by the owner at the time. Squinting, arising from unequal power of the eyes, has occasionally been cured by shading the stronger eye, so as to lay it up in ordinary, as it were, and bring its weaker companion into action, that it may be invigorated, while the other, from want of use, has its power diminished, and an equality is thus obtained between them. During acute bodily suffering, the eye is thrown into the same position, the will having in consequence withdrawn from regulating its movements. At the point of death, the voluntary muscles having lost their power, the eye is left to the operation of this muscle, and the bystanders suppose that the dying person experiences great agony, while in fact, pain and suffering have in all probability ceased for ever. So, likewise, we observe, on lifting the eyelid of the sleeper, that the eye is turned in this direction, as occurs, too, in fainting, and other conditions of suspended animation.

We perceive, then, that the fourth pair are nerves capable of acting independently of the will, whereby they are distinguished from those whose action entirely depends upon it. At the same time, the will is capable of exerting a certain degree of influence upon them; but they do not obey its injunctions so promptly as those of instinct and feeling. Ogling may be imitated, but it is only an imitation at best, and often a failure.

Facial.—The seventh nerve, according to the numerical arrangement, consists of two portions, or rather two distinct nerves, differing in texture, origin, distribution, and function. The auditory has been already described. The portion we have now to examine receives the name of facial, from its extensive ramification on the face. It arises between the olivary and restiform bodies, that is, between the anterior and posterior columns, close to the pons. Looking at this part of the medulla oblongata, we perceive an excellent example of the relative position, as to the origin of the three orders of motific, respiratory, and sensific nerves. The sixth, a motific, proceeds from the anterior columns; the facial, a respiratory, from between the middle and posterior; and the auditory, a sensific, from the back part of the posterior columns, all springing from nearly the same horizontal plane. The facial nerve, although it emerges at the point mentioned, is formed of a number of filaments, some of which are connected with the anterior, others with the posterior, while the remainder spring from the respiratory tract, so that its origin is complicated, in accordance with the variety of uses to which it is applicable, for it cannot be considered as performing exclusively any one function in particular, but may rather be held as representing the combined character of a regular nerve, and of one of instinctive motion. From the medulla it passes forward, accompanied by the auditory, and along with that nerve enters the internal auditory passage. It traverses a canal of the temporal bone, in which it is associated with a branch of the fifth. Emerging from this canal, it forms connexions with the great sympathetic, and then penetrates the parotid gland, in the substance of which it divides into branches, which, escaping from the gland, are spread out upon the head, face, and side of the neck. This expansion of the facial nerve has been compared to a goose's foot; one division proceeds upwards to the temple, to distribute its filaments to the scalp, the forehead, and upper eyelid, establishing connexions with the occipital nerve, and with the frontal branch of the fifth; another crosses the face, sending numerous branches to the cheek, upper lip, nose, and lower eyelid, where it is interlaced with the facial branch of the fifth; a third plexus passes down to the chin and lower lip, where it meets with a branch of the third of the fifth; and lastly, some of its branches proceeding downwards to the neck, to form connexions with the eighth and ninth cerebral, and with some of the inferior cervical nerves.

The extensive distribution and numerous connexions of this nerve have gained for it the name of the smaller sympathetic. It is to be observed that it nowhere sends branches to parts which do not besides derive nerves from other sources. It is therefore reasonable to suppose that the two sets of nerves transmitted to such parts have different offices to perform.

Man is pre-eminently distinguished by the vast scope of his intelligence; and the numerous relationships of family alliance, of friendship, and of other social ties, call forth and exercise the affections of his heart, and the emotions of his soul. These mental conceptions excite his corporeal frame, which, on its part, is admirably fitted for declaring the state of the feelings within. How expressive is the face of man! How clearly it announces the thoughts and sentiments of the mind! How well depicted are the passions on his countenance!—tumultuous rage, abject fear, devoted love, envy, hatred, grief, and every other emotion, in all their shades and diversities, are imprinted there in characters so clear that he that runs may read! How difficult, nay how impossible is it to hide or falsify the expressions which indicate the internal feelings! Thus conscious guilt shrinks from detection, innocence declares its confidence, and hope anticipates with bright expectation.

We admire the actor in proportion to the success with which he imitates the expression of the passions and feelings; indeed the great difficulties which he has to contend with are sufficiently manifest, from the rarity with which success crowns the efforts of the artist in pourtraying the effects even of one class of passions on the body, for tragedy and comedy each essentially consist in displaying the impressions of the respective passions and emotions which they are calculated to illustrate. The incidents of the plot, and the sentiments to be conveyed, are all furnished to the performer constructed with the most refined skill, and clothed with the most glowing and appropriate language, so as to produce the clearest conception of the meaning which is to be developed; yet, however accurately the actor may judge of the intention of the author, howsoever justly he may appreciate the character he has to perform, and however anxiously he endeavours thoroughly to imbue his mind with the sentiments which are supposed to have actuated the hero he represents, the great difficulty is to embody these conceptions, to exhibit the corresponding expressions in the countenance, the attitudes, and the tones and inflexions of the voice; artfully to combine and associate the proper muscles, to call them into action to the necessary extent, with due force and velocity, to vary them in accordance with circumstances, and in no instance to outstep the modesty of nature;—to do all this effectually requires an original combination of talent which falls to the lot of few, and a laborious study as unremitted and intense as is required by any profession whatever.

On the other hand, let the most simple and least refined individual labour under revenge, jealousy, or grief, or let him be actuated with joy, satisfaction, or mirth, and immediately he expresses the feeling in his countenance in language which cannot be mistaken,—not in imitation, but in reality;—and yet we admire the imitation more than the reality, because we seldom reflect on the wonderful perfection of the machinery by which these expressions are effected,—looking upon it merely as a matter of course, just as we admire an excellent picture, while the landscape it depicts may not gain from us even a moment's attention, from being commonplace, and every day before our eyes.

By cultivation the intelligence of the mind is expanded, the passions regulated and controlled, and the sentiments and feelings unfolded. All the original and acquired modifications variously affect the expression of the countenance, so that in time it receives a stamp and impress according to the predominating character of the individual. We thus unconsciously draw an inference as to the disposition of a person we see for the first time; from the expression of the face, we either feel that there is something repulsive in his look, or else something amiable and attractive, which leads us to desire a further acquaintance with him. It is on facts like these that physiognomy rests; but however correct physiognomy may be in theory, so many controlling and modifying influences operate, according to an infinite number of different circumstances, that in practice it must totally fail, as experience shews.

The fifth nerve is distributed to the same parts on which the facial is ramified on the face, and the respective purposes to which they are subservient have been established from a great variety of experiments performed upon the lower animals, and from observations made on man. When the facial nerve is divided, or its functions suspended by disease or accident, the side affected loses all power of expression, although sensation remains unimpaired, while by division of the branches of the fifth pair sensation is entirely, or at least in a very great degree, abolished. The motions of the face therefore undoubtedly depend upon this nerve, and that the influences it transmits are of a mixed character, appears also sufficiently established. We have had occasion to remark that the determinations of the will are communicated to the muscles brought into action, by being transmitted in the course of certain fibres; that from these fibres spring the nerves, which convey the commands to the muscles, constituting the nerves of voluntary motion. Such motions are at first imperfectly performed, for the muscles require to be educated and drilled before they are taught properly to co-operate with each other. Thus, they must undergo education before they can be effectually employed in walking; but having mastered the task, they continue to perform it so promptly and readily that no effort of the will is apparently required, and the necessity for its interference and superintendence is only discovered when, from poisons, disease, or other causes, the nerves are injured, or the will becomes dormant or inadequate.

All the motions performed by the purely voluntary muscles are at first executed awkwardly, but by practice are rendered easy. In the various movements performed in different arts with the utmost nicety, we see the muscles employed in the most complicated movements without the slightest apparent effort. The experienced performer on the piano runs over the keys of the instrument with the greatest precision, as it were intuitively, however awkward her first performance may have been.

There are, on the other hand, various motions in the animal body, which are perfectly executed from the first without previous practice, and in which the different muscles combine with the utmost accuracy, as necessity, passion, or feeling may dictate. Such are the motions essential to breathing, deglutition, and expression in the features of the countenance. These motions are performed independently of the will, and its interference rather tends to disturb and derange than to perfect them. The facial nerve communicates the purposes of the will to the muscles of the face; at the same time it is capable of calling them into action under the influence of instinct and sympathy. Many examples might be quoted illustrative of the dependence of these instinctive movements upon the facial nerve: the following case, which has come under our own observation, may however suffice.

A youth fell from a wall ten feet high on a hard footpath, and was taken up insensible. Half an hour after he was found in the same condition; blood flowed from the left ear, behind which, from external marks, it was evident the head had been struck. After the adoption of the necessary measures the more urgent symptoms were overcome; still, notwithstanding close attention and prompt treatment, he made but a slow recovery, nor have the effects even now, nine years after the injury, been entirely removed. While he lay in a state of insensibility, with laborious breathing, the difference between the right and left side of the face was most striking: the right was thrown into a state of great agitation, and frequently affected with convulsive twitches, the eyelids contracted, the nostril dilated, and the angle of the mouth drawn up spasmodically on every inspiration. On the contrary, the left side remained in a state of perfect placidity. After his recovery from the more dangerous consequences it was ascertained that the left side of the face had sustained permanent injury, which no means that were had recourse to had the effect of removing, though they were neither few nor impotent. His speech was also affected, having become hesitating and stammering. The unusual expression of his face and impediment of speech attracting the attention and ridicule of his thoughtless associates, he became morose in his temper, and unsocial in his habits.

He is now a very athletic young man, but still prefers solitude with his books, and is keenly alive to the peculiarities of his features and speech. Among those with whom he is in habits of intimacy, and when he is off his guard, it is extremely curious to watch the changes of his countenance. If he laughs it is only with one side of his face; when he frowns the left side remains in a state of placid indifference, as is the case whatever mental excitement he may be under at the time. He possesses voluntary power over the muscles affected as completely as ever, and the sensibility has never in the slightest degree been impaired. Sensation depending on the fifth pair, and that nerve having escaped injury in this instance, feeling remains entire. The commands of the will continue to be communicated to the muscles through the facial nerve, which received the shock, while the impulses of sympathy are no longer transmitted by it.

Eighth Pair.—These nerves consist of three distinct portions, different in their course and distribution, though they arise from the same tract. The first has its origin between the olivary and restiform bodies; the second springs by several filaments in the same line immediately below the first; and the third portion arises as low down from the spinal marrow as opposite to the fourth vertebra of the neck, ascending along the spinal canal, and entering the skull to join the other two; still, however, proceeding from the same tract, and lying between the anterior and posterior roots of the cervical nerves. The three divisions, besides their distinct origin from the respiratory tract, have also connexions with the anterior columns of the spinal cord, and consequently, like the facial, combine the three functions of sensation, of voluntary and of instinctive motion.

The first portion being distributed to the tongue and throat is named *glosso-pharyngeal;* the second, from its extensive distribution, is aptly termed the wandering nerve, or *vagans;* and the third, from appearing like an accession from the spinal marrow to the cerebral nerves, is called the *accessory*. It seems advisable to treat of each of these separately, for they only come in contact as they are about to escape from the cranium, which they do along with the internal jugular vein, far back in the base of the skull: immediately on their exit they establish connexions with the great sympathetic.

The Glosso-Pharyngeal passes forwards, and in its course forms connexions with the facial. It sends off branches, which form a plexus or network round the pharynx, distributing its ultimate ramifications to the root of the tongue, the almonds of the throat, and the mucous follicles towards the base of the tongue. We have found that the ninth pair is ramified upon the muscles of the tongue, in connexion with the voluntary movements of that organ; but the tongue being an instrument employed in many instinctive movements, requires the influence of appropriate nerves, that it may be ready immediately to perform any task which may be imposed upon it, without previous tuition, such as it requires to exert immediately after birth in sucking. The instinctive movements connected with deglutition, and the regulation of the entrance to the air-passages, equally demand nerves from the same source. The contributions of this nerve to the almonds of the throat and the mucous follicles shew that it is not merely to be considered as a motific nerve, for in these instances it is connected with secretion. Indeed, mistakes are very apt to be committed in limiting too much the function of nerves. It ought constantly to be borne in recollection that the function of the nerve becomes modified by the organ on which it is distributed, that the actions which we see executed in the living body are not the result of one or two parts of the machinery employed, but of the joint co-operation of the whole. At the same time, fixing upon some leading character in the nerves, serves the useful purpose of enabling us to classify and arrange them, that the mind may more easily recognise and retain them in the memory.

Vagans.—On leaving the skull, the vagans sends off two branches; the one passes to the pharynx and upper part of the gullet; the other is distributed to the larynx, and commands the muscles which close the air passage, and supplies the mucous membrane covering it. The trunk of the vagans descends along the side of the neck, included in the same sheath with the carotid artery and internal jugular vein, and enters the chest under the collar bone, between the subclavian artery and vein on the right, and between the left subclavian vein and arch of the aorta. Here a branch is given off, which loops round the subclavian artery on the one side, and arch of the aorta on the other, to return upwards to the larynx, and therefore named the *recurrent*. The recurrent ascends between the windpipe and gullet, to which it furnishes twigs, and is ultimately ramified on the larynx, communicating with the superior laryngeal, and supplying the muscles which open the air-passage. Where the vagans enters the chest, besides giving off the recurrent, it sends branches, which are accompanied by others from the great sympathetic, forming together a network of nerves, which surrounds the divisions of the windpipe, to accompany them in all their ramifications through the tissue of the lungs. Other minute twigs, also associated with filaments from the sympathetic, descend along the aorta and pulmonary arteries to the heart, and along the course of these arteries respectively, through all their divisions and subdivisions, on the one hand to the lungs, and on the other to the whole system, accompanying the blood-vessels throughout their entire distributions. Having given off these important branches, the vagans with its fellow surrounds the gullet, and enters along with it into the cavity of the abdomen, first distributing freely ramifications to the stomach, and ultimately furnishing branches which combine with the great sympathetic in the formation of the great central ganglion of the abdomen, from whence all the viscera of that cavity are supplied with nervous energy.

The functions exercised, and the sympathetic connexions established by this nerve are of the utmost importance and interest. It is very evident that it is not confined to motion, nor yet entirely to sensation; but that it superintends also the secretion from the different surfaces on which it is distributed.

Let us consider, in the first place, the relations established through the medium of this nerve, between the different organs of digestion and secretion. At the upper part of the throat it forms connexions with the nerves of the mouth and nostrils. Throughout the whole extent of the gullet it is plentifully distributed, as it is also upon the stomach; then, along with the great sympathetic, its filaments are extended throughout the whole of the intestinal tube, to the liver, pancreas, and spleen, and to the urinary and reproductive organs.

It is well known how directly the state of the secretions in one part of the alimentary canal indicates their condition throughout. The physician looks at the tongue of his patient, not that it is the seat of complaint, but because its appearance announces to him the condition of organs which he cannot see; and he is thereby enabled to draw an inference as to the nature and extent of the derangement under which they may be labouring. The irritation of the throat also is frequently had recourse to in order to excite vomiting, the connexion between the stomach and that part being so direct through the medium of this nerve; and, conversely, nauseous substances in the stomach produce convulsive movements and a disagreeable sensation in the throat. In fact, the whole train of phenomena connected with nausea and vomiting are explicable from the ramifications of the vagans. The prompt and perfect co-operation, too, of the various muscles engaged in deglutition is to be explained in the same way.

We have already seen how admirable is the consent, and how delicate the tact of the various portions of the stomach and intestinal tube, how opportunely the bile flows into the duodenum at the time it is required there, and how the gastric, pancreatic, and intestinal juices are adapted in quantity, and varied in quality in the different conditions of action and repose. A rupture, in which a portion of the intestine is protruded and pinched, causes sickness and vomiting; the passage of an urinary concretion along the ureter produces the same effect. Derangements of the womb are accompanied with an uneasy sensation at the pit of the stomach, and the feeling of the ascent of a ball to the throat, with the impression of immediate suffocation. And in the same way we might mention an almost infinite number of other examples of the intimate connexions established between the various viscera and the sympathies they display, both in healthy and deranged conditions, which are brought about through distributions of the vagans.

Again, if we turn our attention to the respiratory system we shall equally find evidence of the important part played, and the associations formed through the ramifications of this nerve in the wonderful adaptation and co-operation of the organs of voice and articulate speech, in the secretion of watery exhalation, mucus, and carbonic acid from the lungs, and in the superintendence of the other important functions carried on in respiration.

Lastly, when we consider that the vagans, along with the great sympathetic, supplies the heart, and accompanies all the ramifications of the blood-vessels, the question comes to be, not on what parts is the vagans ramified? but where, throughout the whole system of the body, are its filaments not to be found? In fact, when we reflect that these two nerves are distributed on the circulating organs at large, we perceive that their presence must be universal; that they form the cords through which the sympathies thrill, and the most distant and apparently least connected parts are bound together, and associated into one harmonious unity.

Accessory.—The three portions of the eighth, on their escape from the skull, form connexions with each other, with the ninth facial, with several of the cervical nerves, and likewise with the great sympathetic. The accessory on parting from the rest passes through the substance of a powerful muscle, named from its attachments *sterno-mastoid*, which lies superficially by the side of the neck, and which will be readily seen thrown into action on the head being turned from side to side. The accessory supplies this muscle, and then proceeds backwards, forming connexions with the cervical nerves. Ultimately it distributes its branches to a large muscle, which, with its fellow on the opposite side, covers the back part of the neck and shoulders like a cowl, hence named *cucularis*, and to a third muscle which raises the shoulder blade, the *levator scapulæ*. These three muscles elevate the shoulders, and render them fixed, whereby the muscles extending between the ribs and the shoulders obtain both a fixed point and the advantage of a longer lever, in consequence of which they are enabled efficiently to raise the ribs, and thereby powerfully to co-operate with the muscles of inspiration.

When we take in a full breath we instinctively elevate the shoulders for this purpose; in asthma they are powerfully called into action, and sometimes during the paroxysm the patient may be observed to place his hands upon the table, the better to enable him to raise and fix the shoulders, and in some measure to relieve these muscles. In stage exhibitions, in painting, and statuary, in which the passions are depicted, these muscles are displayed in full action. The elder Kean, especially in the characters of the Jew and Richard, used to throw them into the most vigorous exertion with a powerful effect. The shrugging up of the shoulders is thus another of the means by which the sentiments of the mind are indicated by appropriate external signs.

Phrenic.—This nerve gets its name from being distributed on the diaphragm, which at one time was considered as the seat of the soul. The phrenic and external respiratory are more directly connected with the anterior and posterior columns than the cranial respiratory nerves which we have described,—so much so that they appear merely to be branches of the cervical nerves; at the same time, however, they receive some minute filaments from the side of the spinal marrow, and therefore the analogy is kept up, at least between them and the facial and eighth pair; for we have noticed that on carefully tracing the filaments of the facial, and of the divisions of the eighth, some can be followed to the anterior, others to the posterior, while the greater number spring from the middle tract. On the other hand, the filaments from the middle tract are few and minute compared with the anterior and posterior origins. As in the former instances, we have the combined influence of sensific, motific, and fibres of instinctive movement in the same nerve, the two former predominating over the last in the number and size of the filaments.

The phrenic passes out of the vertebral canal, between the second, third, fourth, and sometimes fifth cervical vertebræ: it runs down the neck, and enters the chest on the outer side of the internal jugular vein. In the chest it passes down by the side of the capsule of the heart, and distributes its branches to the diaphragm, at the same time transmitting twigs which join the great abdominal nervous centre. The phrenic nerves are not the only nerves ramified on the diaphragm, for the lower intercostals send also several branches to it.

External Respiratory.—This nerve proceeds from between the third, fourth, and fifth vertebræ of the neck; it passes under the collar bone, and runs down, crossing the outer surfaces of the ribs about their middle, and distributes its branches to the intercostal muscles, and to the powerful muscles which extend from the ribs to the shoulders, which are occasionally called into action in laborious breathing.

We now perceive in what manner the various organs connected with the important function of respiration are bound together. The eighth being distributed throughout the whole extent of the air-passages, conveys the impressions made upon that surface, and therefore is so far a sensiferous nerve; but the sensations it communicates are of a peculiar kind, and expressly connected with the peculiar functions of the parts, for it does not transmit any idea of the qualities of substances, as hardness, softness, roughness, or smoothness, such as the nerves distributed on the skin announce. Nor will the most ingenious experiments performed on the lower animals shew that they convey the sensation of pain, however numerous the convulsive movements which may be called forth, or however varied the writhings of the poor animal, with which we generally associate agonizing pain, since they have no means of declaring to us what in reality are their sensations. We have little more right to suppose that these are necessarily connected with suffering than we have to believe that the horrible distortions displayed in the countenance of an executed criminal, when the galvanic shock is transmitted along the course of the nerves, are proofs that the body feels, or that the mind is still associated with it.

The ramification of this nerve on the muscles of voice, and on those of the tongue and gullet, shew that it is a motiferous nerve, but a motiferous nerve with peculiar endowments; it not only transmits the commands of the will by which these parts are called into action, but without the necessity of the will forming a determination, or without any authority from the mind, brings them into operation with the utmost promptitude, and combines them with the greatest accuracy, according to the exigencies of the moment. It is therefore not only a voluntary, but also an instinctive motiferous nerve.

The connexion which the eighth pair has with various secreting organs farther shews that it is capable of regulating their functions, and that it brings their action into accordance with the state of the system, or of individual parts; so that the secretions are varied in quantity and quality, as may be suited to the circumstances of the case.

Again, through the instrumentality of the accessory, phrenic, and external respiratory, the muscles employed in inspiration, either in ordinary breathing or when the inhalations are full and laborious, are brought into action, combined and directed with the proper degree of force, velocity, and extent, without the necessity of interference of the mind. Though at the same time they are ready, within certain limits, to obey the mandates of the will, still it is only in a secondary degree, the impulses of instinct being ever held paramount to the commands of the will. No one can suspend to an indefinite extent the movements of respiration. In a short time, however strong may be his determination, he is compelled to give way to the irresistible mandates of instinctive feeling, which requires not the aid of erring reason, nor will it brook the capricious interference of the will, constituting, as it does, the great conservative principle of the animal organism, and endowed with powers which it has pleased the Great Artificer to bestow upon it. Its behests are issued forth along the appropriate channels, and implicitly obeyed, without hesitation or delay.

Further, it may be noticed that the muscles which elevate the shoulders are frequently employed in connexion with the passions and feelings of the mind, as in shrugging up the shoulders, and the various positions the head may be placed in by the muscles which derive nerves from the same source. The extent and degree of action, as well as the number of muscles employed for the purpose of communicating the state of the feelings in ordinary life, varies in different individuals. Some employ numerous gesticulations and much grimace in their intercourse, in expressing their internal conceptions, while others deliver an account of their feelings with an appearance of the utmost indifference. In the majority of instances, however, these are merely conventional modes of conveying ideas, and accordingly vary in different countries and states of society. But when once the passion or emotion is felt in reality, then the display is the same in all, and the agents selected similar.

Connected as this order of nerves is with the different muscles which are engaged in variously depicting the passions, intimately associated as the nerves are which compose it, and universal in their distribution, their arrangement together is calculated to clear up much that would otherwise be obscure, and to combine facts which would otherwise appear insulated and inexplicable. Although, therefore, it has been considered as the weakest part of the classification of Sir Charles Bell, we are inclined to think it one of the most beautiful portions of the interesting and philosophic theory he has erected. In further illustration, the following striking description may be introduced from Sir C. Bell's treatise on the nervous system.

"In terror, we can readily conceive why a man stands with his eyes intently fixed on the object of his fears, the eyebrows elevated, and the eyeballs largely uncovered; or why, with hesitating and bewildered steps, his eyes are rapidly and wildly in search of something. In this way, we only perceive the intense application of his mind to the objects of his apprehension, and its direct influence on the outward organs. But when we observe him farther, there is a spasm on his breast: he cannot breathe freely: the chest remains elevated, and his respiration is short and rapid: there is a gasping and convulsive motion of his lips, a tremor on his hollow cheeks, a gulping and catching of his throat: his heart knocks at his ribs, while yet there is no force in the circulation, the lips and cheeks being ashy pale.

"It is obvious that there is here a reflected influence in operation. The language and sentiments of every people have pointed to the heart as the seat of passion, and every individual must have felt its truth. For though the heart be not in the proper sense the seat of passion, it is influenced by the conditions of the mind, and from thence its influence is extended through the respiratory organs, so as to mount to the throat, lips, and cheeks, and account for every movement in passion which is not explained by the direct influence of the mind on the features.

"So we shall find, if we attend to the expressions of grief, that the same phenomena are presented, and we may catalogue them, as it were, anatomically. Imagine the overwhelming influence of grief: the object in the mind has absorbed the powers of the frame: the body is no more regarded, the spirits have left it: it reclines, and the limbs gravitate: the whole frame is nerveless and relaxed, and the person scarcely breathes: so far there is no difficulty in comprehending the effect in the cause. But why, at intervals, is there a long-drawn sigh? why are the neck and throat convulsed, and whence the quivering and swelling of the lip? why the deadly paleness, and the surface earthy cold? or why does convulsion spread over the frame like a paroxysm of suffocation?

"To those I address, it is unnecessary to go farther than to indicate that the nerves treated of in these papers are the instruments of expression, from the smile upon the infant's cheek to the last agony of life. It is when the strong man is subdued by this mysterious influence of soul on body, and when the passions may be truly said to tear the breast, that we have the most afflicting picture of human frailty, and the most unequivocal proof, that it is the order of functions we have been considering that is then affected. In the first struggles of the infant to draw breath, in the man recovering from a state of suffocation, and in the agony of passion, when the breast labours from the influence at the heart, the same system of parts is affected, the same nerves, the same muscles, and the symptoms or characters have a strict resemblance."

Comparative anatomy affords numerous facts corroborative of the purposes fulfilled by this order of nerves. In fishes, as might have been expected, from the limited number of their sympathies and instinctive notions, their development is limited, and the eighth pair appears to perform the office of the whole. It is of considerable size, and distributed upon the gills and gill-covers, or the organs of respiration, upon the organs of circulation, and upon those of other functions immediately connected with animal life. In the electric eel and torpedo, they are distributed upon the very curious electric apparatus which these fishes employ with so much effect as weapons, and the nerves are correspondently large.

In reptiles, we find the facial nerve added to the eighth; and wherever these animals display sympathetic action, we observe the parts on which these nerves are ramified become involved. The hissing of the serpent shows the commotion into which the respiratory apparatus is thrown, and the inflation of the neck of the hooded snake, while under the influence of rage, affords a similar instance. The croaking of the frog at certain seasons may also be cited as an example.

When we ascend to birds, the number of the respiratory nerves is limited as in reptiles. The distribution of the facial in them is interesting. Instead of proceeding forward to the hard and inexpressive bill, it is turned back over their neck and shoulders, and is large in those which display their passion by the bristling of the feathers of the neck and back of the head. The vocal organs in birds are well known as the instruments by which they are enabled to communicate the feelings actuating them to an infinite extent, and in every degree of modulation. By means of the vocal organs the hen can sound the alarm to her young brood on the approach of danger, can announce to them the discovery of food, or encourage them to take air and exercise; and by the same means she exultingly publishes the fact of her having been delivered of an egg. Her pugnacious husband bids defiance to his distant neighbour, who retorts by declaring his acceptance of the challenge in the vigorous use of his organs of voice.

In mammalia the number of the respiratory nerves is the same as in man, but not nearly so fully developed, nor are the divisions, subdivisions, and interlacements so various as they are in him. We perceive in the different orders of this class of animals great diversities, especially in respect to the facial nerve. In the sheep it is small and simple; in its distribution it becomes larger in proportion to the fifth, and more intricate in its distribution, as we proceed from the graminivorous tribes through the carnivorous, monkeys and apes, up to man, in whom it is developed in the highest degree, in accordance with the versatility and power of expression he possesses in the features of his countenance. The division of the facial nerve on one side of the face of a monkey destroys at once the peculiar activity of its features on that side; and if it be cut on one side of a dog, the animal when under excitement presents a ludicrous appearance—one side of the face remaining in a state of placidity and indifference, while the other presents a condition of great agitation.

FOURTH ORDER. *Regular Nerves.*—When treating of the spinal cord, it was mentioned that it has been completely established by the experiments and observations of Sir Charles Bell, and confirmed by others, that the nerves arising from the cord possess different powers in the two roots from which they spring; that the anterior roots are subsidiary to motion, and transmit the mandates of the will to the muscles, while the posterior are the channels by which sensations are communicated to the seat of perception; that there are thirty pairs of spinal nerves, and that the fifth cerebral in its structure and function is analogous to these. We shall first treat of the fifth, and afterwards classify the spinal nerves, so as to furnish a general view of their distribution and use.

Fifth Nerve.—This nerve arises by two distinct roots, the posterior or sensiferous of which is by much the largest, being as four to one. The filaments of the sensiferous portion can be traced through the fibres of the pons till they become continuous with the fibres of the posterior column or restiform body immediately below the pons. The anterior smaller portion springs from the anterior column between the olivary and pyramidal bodies. Piercing the dura mater, or rather carrying forward a tubular prolongation of that membrane, they reach the side of a depression in the base of the skull, which has been likened to a Turkish saddle, where the anterior swells out into a large knot or ganglion, named after its discoverer the *Gasserian* ganglion; after which it divides into three divisions; the first passing into the orbit, from its connection with the eye termed *opthalmic;* the second, from its distribution being principally to the upper jaw, is called the *superior maxillary;* and the third sent to the lower jaw is named *inferior maxillary.* The anterior root joins the third branch alone, so that the two first are composed of filaments solely from the anterior root, while the third is truly a compound nerve like those which proceed from the spinal marrow. We shall consider the three divisions of the fifth separately.

Opthalmic Branch.—This enters the orbit at the same passage with the third, fourth, and sixth, when it immediately divides into branches; one proceeds forwards, and is reflected on the forehead, where it establishes connections with the frontal plexus of the facial; another re-enters the skull, and accompanies the first pair of nerves to the nose; a third passes to the lachrymal gland. A small twig runs along the optic nerve, to join others from the third pair. Before they combine, a small ganglion is formed on this twig, termed from its form lenticular; from these arise minute nerves, which pierce the coats of the eye, to be ramified upon its interior. The mucous membrane and other secreting organs are supplied from the opthalmic branch, so that extensive connections are established by it.

Superior Maxillary Branch. This passes through a hole a little posterior to the first, and immediately begins to divide into branches, some of which have ganglions formed in their course. The principal branches are sent to the back part of the nostrils, the pendulous curtain and almonds of the throat, where it forms connexions with the eighth; to the palate, gums, and teeth of the upper jaw, and externally to the cheek, upper lip, and nose, where it is intimately associated with the facial. A small twig re-enters the skull, passing by the side of the carotid canal: it sends filaments to unite with the sixth and great sympathetic. It then enters a canal, and for a short space be-

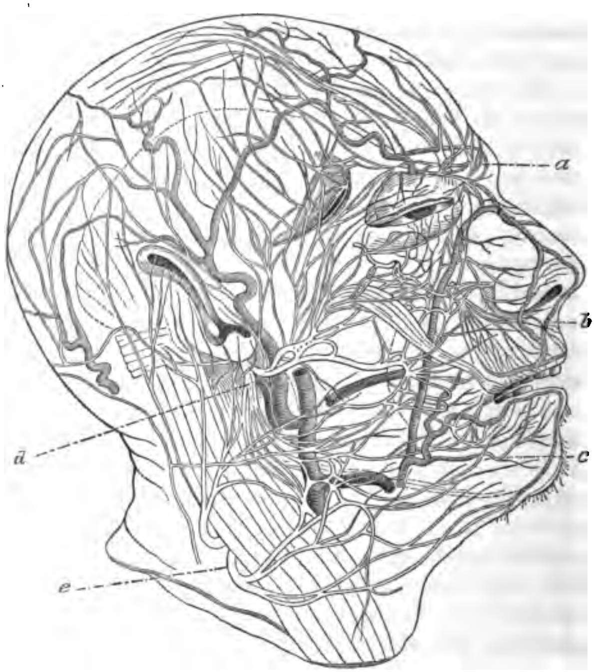

FIG. 23.

comes associated with the trunk of the facial, from which it derives some minute filaments, after which it runs through the drum of the ear, and again emerging from the skull, joins the branch of the fifth, which is distributed upon the tongue, and finally it is expended in the neighbourhood of the submaxillary gland.

Inferior Maxillary Branch, formed of a combination of the sensiferous and motiferous filaments of the fifth. The latter are distributed to the muscles which shut the jaw, and also on those which regulate the posterior orifices of the nostrils; the former are ramified upon the tongue, salivary glands, gums, and teeth of the lower jaw, on the external ear, cheek, chin, and lower lip, maintaining communications with the facial, the eighth and ninth, and with the great sympathetic.

The engraving is here introduced to shew the distribution of the facial and fifth nerves on the face, and in order to give an idea of the manner in which nerves are ramified. *d* is the trunk of the facial, its branches radiating from this situation to the forehead, across the face to the chin, down by the side of the neck; they are seen to communicate with each other, and to join twigs of the three branches of the fifth; *a* is the frontal branch of the fifth; *b* the facial of the same, and *c* its submaxillary branch; *e* are ramifications of the cervical and accessory nerve, forming communications with the facial.

The fifth being profusely distributed upon the integuments of the face, has been unequivocally demonstrated to be the nerve by which feeling is transmitted. From exposure probably to the vicissitudes of external temperature, it is liable to an exquisitely painful affection, named *tic douloureux*, which is sometimes removed by cutting the nerve affected,—the patient preferring the loss of sensibility to the agonizing pain which accompanies the disease. In the cat, the hare, and other animals with large whiskers, the filaments of this nerve have been traced to the bulbs of the hairs, accounting for the delicate tact which these animals are endowed with, and by means of which they are enabled to wind their way in the dark through intricate passages with the greatest facility.

It deserves attention, that the fifth is associated with the organs of the senses of smell, sight, and hearing;

that it exercises that of touch, especially on the lips and tip of the tongue, and that it is the immediate instrument of taste. From the general outline we have given of its distribution, it will be seen that both the first and second branches contribute filaments to the nose, those from the first accompanying the olfactory nerve. Magendie has attempted to prove that these twigs constitute the proper seat of smell, and that the first nerve has nothing to do with that function, though he has seen reason somewhat to modify his opinion. In this he has furnished a notable instance how torturing animals, by what are called experiments, is as apt to mislead and bewilder as elicit truth. It is a source of no small pleasure to know that the conclusions which Sir Charles Bell has arrived at, and the truths which he has succeeded in establishing, were not the result of cruelties committed on our fellow-creatures in the first instance, and that when it became necessary to put them to the test upon living animals, the experiments were previously well devised, and conducted with every consideration of humanity the case would admit of; and in no instance does he have recourse to unnecessary repetitions, furnishing a beautiful contrast to that butcher-like indifference to animal suffering which is so fashionable in the present day, and which is often practised with so little appearance of design, aim, or purpose, that it looks as if it sprung more from the gratification of a depraved and cruel disposition than from the desire for the advancement of science.

Magendie cut the first pair of nerves in dogs, and applied ammonia to the nostrils, when there appeared as much sensibility as ever. He cut the nasal branches of the fifth pair, and the animal no longer displayed evidence of being affected, and therefore he inferred that the fifth was the true nerve of smell. Now, in the first place, ammonia has no odour; it is a powerful stimulant, but does not communicate to us any impression such as the olfactory nerves convey; as a powerful stimulant it is calculated to rouse the common sensibility of the nostrils, which depends upon the fifth. The other pungent stimulants he employed with the view of upsetting long established opinions, namely, the oils of lavender, of turpentine, and so forth, not only impress the first pair with their odour, but likewise rouse the sensitiveness of the fifth. Then as to the fifth pair being necessary to the exercise of the sense of smell, without having recourse to mangling animals, there was little or no ground to doubt that the destruction of the fifth pair would be attended with derangement of the sense of smell, since the organ by which it was exercised had lost its integrity.

From the distribution of the first branch of the fifth pair upon the iris, the lachrymal organs, and nose, we have an explanation of the connexion which subsists between these parts, affording an example of sympathy, not of that kind which calls forth motion, but sensation; yet although there appears to be a sufficient number of facts to establish the existence of sympathy of sensation, some contend for its being limited to the respiratory system of nerves, and account for the connexions which are displayed between such parts as those on which the first branch of the fifth pair is ramified to the communications with the pathetic and facial. But however that may be, it is well known that pungent substances applied to the nose produce a copious flow of tears; the iris will also be found to contract, and when the curtains are opened in the morning, and a sudden glare of light is thrown upon the eyes, sneezing is apt to follow from the transference of excitement to the nose; and from the connexion which the branches of the fifth establish with the respiratory nerves, the muscles of respiration are powerfully thrown into action, and the air is forcibly expelled through the nostrils. The gratification from snuff-taking does not arise from its odour, but from the stimulus of the sensiferous nerves. When a hearty pinch is taken, the eyes water, the excitement extends to the forehead, the teeth tingle, and the most distant parts are roused. In megrim, relief is occasionally experienced from the application of pungent substances to the nose; hence the use of cephalic snuff.

The twig of the second branch, which we have described as taking a very circuitous route through the drum of the ear, associates this nerve with the organ of hearing, whereby it becomes influenced by the vibrations of sound, accounting for the teeth being set on edge by grating sounds, such as the sharpening of a saw.

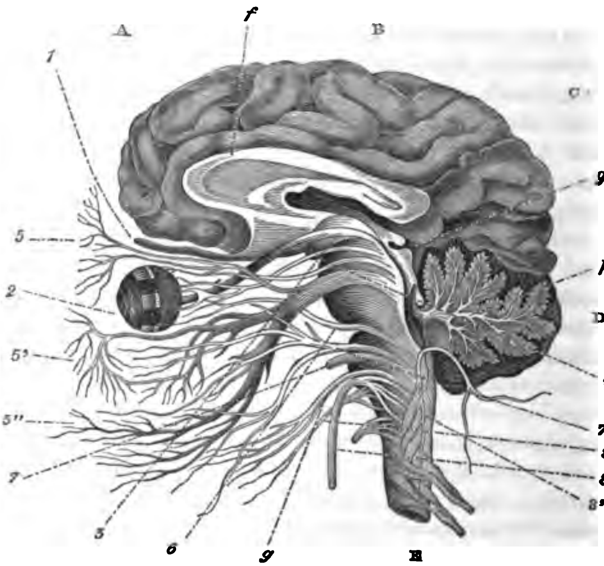

FIG. 24.

The lips are well known to be delicate instruments of touch, deriving their sensibility from the second and third branch, which are intimately associated with the facial, and are the immediate seat of the gratification of kissing, so far as that is merely a sensual act.

From various experiments it appears sufficiently established that the fifth pair constitutes the more immediate seat of taste, the second branch supplies the palate, and a large portion of the third is distributed to the tongue. We perceive, therefore, that the fifth is brought directly into communication with all the senses; that it confessedly exercises the function of touch, and forms the essential instrument of taste; that it is affected by pungent odorous substances, by light, and by sound. In the absence therefore of special organs of sense and of appropriate nerves, this may convey impressions communicating to the animal some conception of these qualities of bodies.

As it is from the fifth that the teeth derive their nerves, so we can comprehend how toothache should be accompanied with such exquisite pain; why the salivary glands pour out their fluids abundantly during the paroxysm; and the reason of the extension of pain to the ear, the face, and head, when the dental nerves are exposed from caries of the teeth.

The engraving is intended to exhibit the relative size and situation of the most important parts of the cerebro-spinal portion of the nervous system. A is the anterior lobe of the cerebrum; B the middle lobe; and C the posterior lobe; *f* is the great commissure; *g* the tubercles; D is the cerebellum; *h* the arborescent appearance presented by a vertical section of it; E the spinal marrow, with the regular double-rooted nerves arising from it; 1 the first pair, or olfactory nerves; 2 the second, or optic; 7 the auditory portion of the seventh, forming the nerves of special sense; 3 the third; 6 the sixth; 9 the ninth, forming the motiferous nerves; 4 is the pathetic or fourth pair; 7' the facial of the seventh; 8 the glosso-pharyngeal of the eighth; 8' the vagans; and 8'' the spino-accessory of the same, forming three of the five respiratory nerves; 5 is the first, 5' the second, and 5'' the third branches of the fifth nerve.

Spinal Nerves.—After what has been already stated, it is unnecessary to enter at any length into the examination of the nerves arising from the spinal cord, since they are all similar in their construction and in the functions which they perform. On tracing the fibres proceeding from the anterior column of the cord, we find that they swell into a ganglion before they are joined by those from the anterior column. Although both sets of filaments are wrapt up in the same covering or neurilema, yet they never actually coalesce or anastomose with each other, but each filament remains separate, however intricately it may be interwoven with others, from its origin to its ultimate termination.

Our notions of sensibility are chiefly derived from our experience of it on the surface of the body. According to common belief, the deep-seated parts are possessed of a more exquisite sensibility than the surface, but the very reverse is actually the case. When the surgeon performs an operation, he with truth assures the patient that when he has cut through the external parts, the most painful part of the operation is over; and the patient bears up with greater ease in the further steps of the operation, where the knife is plied among the deep-seated parts. The bone is sawn through, the muscles, tendons, and ligaments cut and lacerated, and even burnt with a red-hot iron, and yet the patient experiences little or no suffering; at least the pain he feels is derived from the wounded and divided nerves which communicated with the integument.

This high degree of sensibility in the integuments of the body is a wise and benevolent provision, whereby we are warned to avoid not only what might injure the skin itself, but also endanger internal parts. The skin, therefore, from being endowed with acute sensibility, becomes an admirable protector to the whole body. The extremes of heat and cold, which might prove injurious, produce their painful impression; mechanical causes rouse by their sharpness, roughness, or hardness; acrid and corrosive chemical agents induce uneasy sensation—by all which we are admonished to shun the cause producing such disagreeable effects.

The sensibility varies much, not only in degree, but in kind. The skin is sensible to variation of temperature, but not to the uneasy sensation arising from over-exertion; while the muscle is liable to the sense of fatigue, but not to the vicissitudes of temperature. In the same way every other organ of the body is endowed with a peculiar sensibility, which is best adapted to its structure and the purposes of its existence: the eye is sensible to light, the ear to vibrations of sound, the nose to odours, and so forth. These sensations are conveyed from the point on which the impression has been made, upwards along the sensiferous filaments of the nerves to the seat of perception, the brain.

The mind having determined a purpose, the mandate is issued forth from the brain along the motiferous nerves, and transferred to the muscles which are required to carry it into effect. The filaments which communicate the sensations in one direction are bound up in the same sheath with those by which the command is transferred on the other, so that they become thus associated with each other, and in harmony carry on together their respective functions, though the disorder or even the total destruction of one is not necessarily followed with complete loss of power in its companion.

The spinal nerves are generally classed by anatomists according to the portions of the spinal column from which they issue, as the neck, back, loins, and pelvis, forming the *cervical*, *dorsal*, *lumbar*, and *sacral* nerves. Of the first we have eight; of the second twelve; five of the third; and five of the fourth. They all establish connexions with the great sympathetic. On their escape from the spinal canal, they divide into anterior and posterior branches, the latter of which are small, and ramified on the muscles and parts in their immediate neighbourhood. The former are more extensively distributed, especially those which supply the arms and legs. The cervical nerves form, by their anterior branches, direct connexions with the fifth, facial, eighth, and ninth cranial nerves, and with each other, so as to form a plexus or net-work. By their frequent interlacements, they are more closely associated together.

The four lower cervical, and the first dorsal proceed to the axilla or arm-pit, where they form an intricate net-work, termed *axillary plexus*. It may be observed that the intricacy of a plexus bears some relation to the variety of the movements performed by the parts on which the nerves forming the plexus are distributed. Accordingly, in the arm of man, where the variety, extent, and complex combinations of the movements infinitely surpass the simple and limited motions of the corresponding limb of the horse, the ox, or the sheep, although the number of the nerves is the same, they are not equal in proportional size, and more especially are they distinguished in these animals by the simple construction of the plexus. The same holds with respect to the leg, where we also find a plexus at the commencement of the nerves destined for it. Although in man this plexus is less complicated than that of the arm, in accordance with the less varied movements of the lower limb, it is still more simple in such animals as are above referred to, in which the motions are limited.

Some of the nerves from the axillary plexus are distributed to the parts in the vicinity of the shoulder, others extend to the muscles and integuments, as far as the wrist, while others again proceed to the hand and points of the fingers; the last are composed chiefly, if not entirely, of the filaments of sensation, and are delicate organs of touch.

The dorsal nerves are characterized by their principal branches, with the exception of that of the first, running along the inferior margins of the ribs; their posterior ·es supply the muscles and integuments of the back; their anterior run forward to be distributed on the intercostal muscles, and those of the chest.

The lumbar and sacral nerves are connected with each other in the plexuses which they form, having supplied the muscles of the loins and the walls of the abdomen. Their principal branches proceed to the lower limb, some being confined to the hip-joint, while others extend to the extremities of the toes. It may be observed that the same nerve is usually distributed on muscles which are commonly associated with each other, as those which bend or extend a joint, those employed in rolling it inwards or outwards. The last of the spinal nerves send twigs to the extremity of the intestinal canal and urinary bladder, whereby a certain degree of voluntary power is gained over them, and they become endowed with common sensation; other branches are distributed to the external organs of reproduction, imparting to them sensibility.

FIFTH ORDER. *Ganglionic Nerves.*—The portion of the nervous system we have had under consideration comprises what is termed the cerebro-spinal. We have seen that it comprehends the material instrument of thought, perception, and sensation—that it is the source, and furnishes the channels, of voluntary motion, and of instinctive movements and sympathy.

We have now to direct our attention to another portion, whose functions are independent of the cerebro-spinal system, though intimately associated with it. None of the names applied to this order are without objection, when used in their strict signification. It was supposed, from its extensive distribution, that it constituted, if not the only, at least the principal channel by which sympathies were transmitted. From this hypothesis it got the name of *great sympathetic* conferred upon it. But sympathy has been shewn to be independent of it, excepting in so far as it receives filaments from the cerebro-spinal nerves. In consequence of its numerous connexions with the spinal intercostals, it is called the *great intercostal*, but it is in no especial manner connected with the intercostals, and exists in several animals which have no intercostals, and in many which have no ribs. It may also be noticed in passing, that the epithet great has been bestowed upon it, not from its size, but from its real or supposed importance. Indeed, were bulk a measure of the importance of the different parts of the nervous system, the great sympathetic must sink very low in estimation, for one of its distinguishing characters is, that its filaments are extremely minute. It is named ganglionic, from the numerous ganglions established in various parts throughout its distribution. But we have already seen that ganglions are also found in the sensiferous nerves, and therefore are not peculiar to the order in question. Still, the employment of these names, merely in an arbitrary sense, without reference to the circumstances from which they have been applied, is attended with no inconvenience or disadvantage.

Ganglions are masses of nervous substance, varying in their size, shape, and in the connexions they form; they are composed of a mixture of cineritious and medullary matter, inextricably incorporated together. Various opinions have been entertained as to their use. The most probable appears to be that which holds them as the centres of peculiar nervous power. It is generally close to, or in the substance of, a ganglion, that the sympathetic forms connexions with the cerebro-spinal system.

At one time the sympathetic was considered as a mere offset or emanation of the cerebro-spinal, and as such described as proceeding from the sixth, and second branch of the fifth. By way of illustration, we may here advert to the mode of connexion with the sixth. The sixth, on its passage through the cavernous sinus, has a communication established with the great sympathetic, by a twig or twigs, which accompany the internal carotid artery through the skull, in the course of which there is usually a ganglion, termed the cavernous. Now the question is, whether does the sixth give off or receive this branch of union? If it gave it off, we should expect to see the sixth diminished, which it is not, neither is it increased in proportion to the twig of connexion. The inference, therefore, which may be drawn is, that there is a mutual interchange of filaments between the sixth and sympathetic, that filaments pass from the former to the latter, and again, that filaments from the sympathetic accompany the ramifications of the sixth throughout its whole distribution.

This may be taken as an example of the character of the intercourse which subsists between the ganglionic and cerebro-spinal systems, and such connexions being formed with every cerebro-spinal nerve as concomitants, where-ever there is a filament of the one, there also is there a filament of the other; and thus the distribution of both is universal.

A plexus is, as we have already seen, an interlacement of fibres, as in the axillary plexus. The commissure of the optic nerves may also be cited as an example. A similar interlacement of fibres exists in ganglions, so that a ganglion is not only a mass composed of a mixture of grey and white matter, but likewise a network, where the nervous filaments are interwoven with each other. The ganglionic system is not only distinguished by the number and variety of its ganglions, but also in the prevalence of plexuses. Accompanying, as they everywhere do, the blood-vessels, they are found sheathing the larger arteries with a covering of intricate network.

In a general and limited sketch such as the present, it is impossible to advert to the many interesting physiological bearings in which the ganglionic system may be viewed, as well as its numerous and important relations, both in respect to health and disease, even were the present a proper occasion to enter at length upon such discussions. We shall therefore content ourselves by taking an instance of its importance, which may afford a glimpse of its proper use in the animal machinery.

We have seen that the function of the heart depends on its contractility. There have been many instances of fœtuses born, some without a brain, and others destitute both of brain and spinal marrow, and yet, throughout the life of such monsters, the heart continued to circulate the blood as completely as in the perfect fœtus. We know that the heart, when torn from the body, does not instantly cease to contract; that in some animals it continues to palpitate for hours after removal. The motions of the heart appear therefore to be independent of the cerebro-spinal system. We possess no direct power over the heart's action: we can neither hasten nor retard, nor can we increase or diminish the force of its pulsation. But there is not a passion or emotion of the mind, or disease in any other organ the most distant, with which the heart does not sympathize, and in consequence become affected, in the frequency, force, and regularity of its action. These affections we are enabled to explain by the filaments it derives from the respiratory vagans.

The heart, in its healthy condition, is destitute of sensation, at least in the common acceptation of that term. We formerly alluded to the case of a youth of noble family brought under the notice of the illustrious Harvey by the direction of Charles the First, where an opportunity was afforded for proving the absence of common feeling in the heart. In this case, after a fall, an abscess had formed, and burst externally. When the wound healed, an opening was left by which the heart and lungs were exposed, To use the words of Harvey, "When I paid my respects to this young nobleman, and conveyed to him the king's request, he made no concealment, but exposed the left side of his breast, when I saw a cavity into which I could introduce my fingers and thumb. Astonished with the novelty, again and again I explored the wound, and first marvelling at the extraordinary nature of the cure, I set about the examination of the heart. Taking it in one hand, and placing the finger of the other on the pulse of the wrist, I satisfied myself that it was indeed the heart which I grasped. I then brought him to the king, that he might behold and touch so extraordinary a thing, and that he might perceive, as I did, that unless when we touched the outer skin, or when he saw our fingers in the cavity, this young nobleman knew not that we touched the heart."

In inflammation, rheumatism, and other morbid affections, the heart becomes exquisitely sensible. The agony it suffers is now announced to the seat of perception, and this we can account for by the interchange of filaments between the ganglionic and regular nerves. The sympathetic movements, and the morbid sensibility of the heart can therefore be explained as depending upon the filaments which it receives from the cerebro-spinal system. Still there remain to be accounted for its independent contractility, its peculiar sensibility, or innate vitality.

The facts derived from comparative anatomy and physiology, and from the gradual development of the nervous system in the higher tribes of animals, all furnish strong evidence that the peculiar vitality of every organ in the body directly depends upon the ganglionic nerves. The structure of these nerves, formed as they are everywhere of cineritious and medullary matter, their independence of every other part of the nervous system, the independence of the different portions, even without reference to each other, and their universal distribution, all corroborate the opinion that they are capable of receiving impressions, of instituting action, and communicating excitement to the action of other tissues, such as that of muscular contractility, of absorption, secretion, and so forth, according to the structure and function of each organ; and that there nowhere exists a paramount centre of reference, such as the brain constitutes to the cerebro-spinal system, but that each part is independent of every other, though all are linked together by filaments of connexion, so that the different individual parts may be combined into one confederate harmonious system.

The heart, therefore, contracts from being furnished with muscular fibre, the proper office of which is contraction; we infer that the contractility is put in action by the muscular fibre being associated with nervous matter capable of furnishing the stimulus to contraction; that this power of instituting stimulus, as well as proper sensibility of the heart, and of every other organ in the body, is inherent in the ganglionic system of nerves.

The ganglionic nerves, properly speaking, cannot be said to have any particular origin or course of distribution, every organ in the body possessing through them its own independent seat of nervous energy, with which its special function is more immediately connected. Nevertheless, for the sake of description, it is necessary to have recourse to certain starting points, from which the various bearings may be taken, just as the geographer employs the arbitrary lines of meridian and longitude on a map.

There are four positions which may conveniently be fixed on as central points at which the ganglionic nerves establish numerous connexions with those of the cerebro-spinal system, and with each other, composed of a ganglion or ganglions with intricate interlacements, thus forming gangliform plexuses. The first is situated on the fore part of the two or three first vertebræ of the neck; the second at the lower part of the neck and upper part of the chest; the third at the upper part of the abdomen behind the stomach; the fourth in the pelvis at the extremity of the vertebral column. They may be termed respectively the cervical, thoracic, abdominal, and pelvic ganglionic centres.

Cervical Ganglionic Centre.—The superior cervical ganglion lying on the front of the two or three first cervical vertebræ, generally of a fusiform shape, may be taken as the focus of this gangliform plexus. At this point the great sympathetic establishes connexions with every one of the cerebral nerves, by filaments which may be traced to each, in several of which ganglions are formed,—as the lenticular in the orbit, the cavernous within the skull, and the spheno-palatine, otic, and submaxillary connected with the fifth. It anastomoses freely with the facial and eighth, with the ninth, and with three or four of the superior cervical nerves. Reinforced by filaments from the facial and vagans, its twigs extend along the ramifications of the external and internal carotid artery, forming sheaths which may be traced accompanying the larger divisions, but becoming too minute for detection by the eye, even when aided by the microscope, though there is no reason to suppose that their distribution is limited to the larger trunks. According to this view, therefore, their distribution must be co-extensive with that of the arteries; and consequently the brain itself is supplied with nerves, as are likewise the nerves themselves, just as we have blood-vessels ramified upon the heart and coats of the blood-vessels. From this nervous centre we therefore perceive connexions established and filaments extended to the brain, the organs of sense, and those of the secretions connected with them, to the organ of voice and deglutition, and the different muscles which put them in motion, and to those subservient to the movements of the neck. Lastly, a branch or branches run down behind the sheath of the common carotid and internal jugular vein, considered as the continuation of its trunk.

Thoracic Ganglionic Centre.—At the lower part of the neck, opposite the fifth, sixth, and seventh cervical vertebræ, are placed two or three ganglions, the superior termed *middle*, and the lower *inferior cervical ganglions*. They form numerous connexions with the vagans, phrenic, and nerves of the axillary plexus. The frequent interlacements surround the blood-vessels proceeding from and entering the chest. Nervous sheaths accompany the common carotid artery upwards, to unite with those from the superior ganglion, along the vertebral artery to the spinal marrow and brain, and along the artery of the arm throughout all its divisions and subdivisions to their ultimate terminations. Others run along the air-tubes to the lungs associated with the branches of the vagans to the heart, and along the gullet; so that from this centre we have emanating the filaments which are connected with the arm and upper part of the walls of the chest, the organs of respiration, the organs of circulation, and the gullet. The great sympathetic, proceeding down the back part of the chest behind the investing membrane, establishes connexions with the twelve intercostal nerves, forming a ganglion opposite to each. Springing from four to seven branches, there are two nerves which enter the abdomen through the diaphragm by separate passages, named from their distribution on the viscera the *great and small splanchnic nerves.*

Abdominal Ganglionic Centre.—By the two splanchnics, reinforced by branches from the vagans and a few filaments from the phrenic, an exceedingly intricate nervous centre is formed of an assemblage of ganglions and plexuses at the upper part of the abdomen, lying upon the diaphragm behind the stomach. On each side there is a ganglion larger than the rest, which has received the name of semilunar, from the shape it usually presents. Each semilunar ganglion forms connexions with its fellow of the opposite side, surrounding one of the principal trunks from the aorta; and as we have got two moon-shaped ganglions, so have we here a solar plexus. The nerves of the right and left form here, by numerous intricate interlacements with an assemblage of ganglions, a great nervous centre, from which issue filaments that sheath the arteries arising from the abdominal aorta, and accompany them in their distribution to the stomach and intestinal canal, to the spleen, pancreas, and liver, to the kidneys, to the organs of reproduction, and lastly, along the bifurcations of the aorta to the lower limbs.

Pelvic Ganglionic Centre.—Filaments of continuation pass from the thorax into the abdomen behind the diaphragm, and run down by the side of the vertebræ of the loins, sending filaments to the plexuses from the abdominal centre. Entering the pelvis, they pursue their course in the front of the sacrum, at the extremity of which the sympathetics of each side unite together in the formation of a single ganglion, named *ganglion impar*. Throughout the course of the filaments of continuation, connexions are established and ganglions formed, as in the regions of the neck and chest, with the spinal nerves. In the pelvis, twigs are sent off to the extremity of the intestinal canal, to the urinary and reproductive organs, along the arteries ramified within the pelvis, and to accompany those which pass out to be distributed externally.

CHAPTER VIII.

SIGHT.

Arrangement of the different parts of the Apparatus of Sight—Appendages of the Eye—The Orbit—The Eyebrows—The Eyelashes—The Eyelids and their Motions—Lachrymal Apparatus—Motions of the Eyeball—The Globe of the Eye capable of Motion in every direction—The Muscles by which the movements of the Eye are effected, as under the command of the Will, and by Instinctive Feelings—How we see an object single with two Eyes—Regulation of the Sphere of Vision—Compound Eyes of Insects—Some species of Butterflies furnished with 34,650 Eyes—Squinting—Various Causes of—The Globe of the Eye—Sclerotic Coat gives protection, and affords insertion to other parts—Choroid Coat—Furnished with a Dark Secretion to absorb Light—Its intimate connexion with the Retina—The Iris, or Variegated Curtain—The hole in its centre, the Pupil—Regulates the quantity of Light admitted in the Posterior Chamber—A single object held close to one Eye, several Images produced, and the object appears multiplied—Transparent parts of the Eye—Aqueous Humour very rapidly renewed—Adaptation of the Eye to near and distant, to large and minute objects—Crystalline Lens—Its beautiful organization—Vitreous Humour—The Retina the immediate Organ of Sight—Manner in which the Retina may see its own Blood-vessels—Insensibility to Light at the entrance of the Optic Nerve—Seat of distinct Vision—Curious effects from indirect Vision—Continuance of the Impression of Light—Cause of the appearance of Light when the Eye is struck—Refraction of Light—Short-sightedness—Long-sightedness—Sunbeam decomposed into seven coloured rays—Means by which we estimate the size and distance of objects, by the Visual Angle, the Intensity of Light, Shade, and Colour, and by contrast with other known objects.

LIGHT has a considerable effect upon the whole of animated nature; it promotes the growth and vigour of vegetables, and produces powerful and beneficial effects on the health and comfort of animals, from the highest to the lowest. The more perfect animals are furnished with instruments by which they are enabled to appreciate several of the properties of light, whereby they become acquainted with near and distant objects, obtaining from this source conceptions which vastly extend the sphere of their knowledge, and contribute to their gratification and delight.

The eyes are the material instruments by which we receive our impressions of the different modifications of light. The brilliancy and beauty of these noble organs cannot escape the attention of the most heedless, and their admirable adaptation to the purposes for which they have been furnished us, must call forth the admiration and gratitude of every one who gives the subject even a superficial consideration.

The different parts of the apparatus of sight may be conveniently considered under three divisions; *first*, The appendages of the eye, by which it is protected from external injury, preserved in a condition adequate for its duties, and whereby its motions are effected; *secondly*, The various coats, which perform different functions according to the structure of each, and the humours through which the rays of light pass to be pictured upon the immediate seat of vision; and *thirdly*, The nervous screen which receives the image, and transmits the impression to the seat of perception in the brain, where the mind takes cognizance of it.

Appendages of the Eye.—The orbit is a four-sided vault of a pyramidal shape, composed of seven bones; the margin is rounded, and projects at the upper part over the anterior surface of the eye, whereby that organ is protected from blows or other external causes of injury. It is more complete in man than in other mammalia. The axes of the two orbits, if continued backwards, cross each other, since they diverge somewhat towards the temples, but the divergence is less in man than even in apes, which approach him so nearly in their structure.

The Eyebrows are composed of loose cellular substance, covered with skin, from which spring short bristly hairs, projecting outwards. Like all hairs, they penetrate follicular crypts, and become besmeared with an oily secretion, which preserves their glossiness, so that the drops of sweat which may accumulate on the brow are prevented from trickling over the eyelids, where they might interfere with vision.

Attached to the eyebrows, we have the three following muscles:—Fibres extend from the occipito-frontalis, which are inserted into them, whereby the brows are elevated. Another muscle proceeds from the root of the nose, its fibres spreading out like a fan upon the eyebrow and skin of the lower part of the forehead; this acts as an antagonist to the last, knits the eyebrows, and corrugates the skin of the forehead, hence named the *corrugator*. The third is common to the brow and eyelid; it is formed of a series of fibres, which arise from a little sinew or tendon at the inner angle of the eye, spreading out upon the upper eyelid and brow, over the integuments at the external angle; then it passes inwards, across the under eyelid, to be again fixed to the tendon: from its shape it is called *orbicular*. By this muscle the eye is closed, and, when powerfully thrown into action, it wrinkles the skin around the margin of the eyelids.

These muscles are regulated in their movements by the facial nerve, or the nerve of expression of the face, and it is well known that they are thrown into action by, and become expressive of, the passions and emotions of the mind. In advanced life, the integuments losing their elasticity and becoming relaxed, the skin of the forehead, at the outer margin and on the eyelids, presents furrows which mark the impress of years. Where the stormy passions have frequently called these muscles into powerful action, the markings are deeper, and may leave their traces even in early life; hence the wrinkled forehead, the lowering brows, and streaked eyelids, are equally the result of mental perturbation and of age.

The Eyelashes form beautiful fringes to the margins of the eyelids; they consist of two or more rows of stiff bristly hairs, generally of the same colour with those of the head and eyebrows, but sometimes of a different shade; those of the upper eyelid are longer than those of the lower. They serve to ward off insects, and protect the eye from particles floating in the air. When the eyelashes are humid, the litle drops of moisture decompose the rays of light, and, even independently of humidity, they partly resolve the light passing into the interior of the eye, causing the appearance of a luminous zone around the flame of a candle.

The Eyelids are formed externally of a very thin skin, beneath which the cellular membrane, instead of containing fat, has its cells occupied with a gelatinous semi-transparent fluid. The inner surface of the eyelid, next to the ball, is a mucous membrane continuous with the skin, and named *conjunctiva.* Immediately under the skin the fibres of the orbicular muscle are situated, under which, in each eyelid, there is placed a cartilaginous body, which gives a sufficient degree of tension to the lid, at the same time admitting of the necessary movements. Anterior to each cartilage is situated a row of follicular crypts, for the secretion of viscid fluid which collects on the margins of the eyelids, and especially towards the internal angle during the night, constituting the gummy matter accumulated in the morning. Attached to the cartilage of the upper eyelid there is a muscle, the levator, which arises from the bottom of the orbit, by means of which the eye is kept open. It is entirely under the command of the will, while the eye is shut by the orbicular muscle, whose action does not necessarily require a mandate from the will, in order to perform its function. The advantage of this arrangement is obvious; for had it been otherwise, we might have gone to sleep forgetting to close the eyelid, from which great danger and injury might have happened: but the closure of the eye is not left to our discretion; no sooner do we become drowsy than the eyes begin to close, and if we are desirous of keeping awake, we feel the necessity for exertion to keep them open. The eyelids are not equal in size, the upper being the largest, besides possessing the freest and most extensive movements; it serves as a curtain which covers the delicate organ when not in use, and by its motions diffuses uniformly the tears and mucous secretions over the surfaces. The winking or nictitation of the upper eyelid is performed so rapidly that there is no interruption to the continuance of vision; therefore, as we shall find immediately, the closure and re-opening of the eye must be effected in less than the eighth part of a second; so rapidly indeed are the two movements effected, that the "twinkling of an eye" is used as expressive of the least possible measure of time. The eyelids do not completely prevent the transmission of light when they are closed; for we then still continue capable of distinguishing between light and darkness. When the body has been refreshed by sleep, and the susceptibility, which continued action had impaired, is again restored by rest, on the light falling upon the eyelids in the morning, a sufficient quantity is transmitted to arouse sensibility, and we awake.

Birds are furnished with a third eyelid, formed of a duplicature of the conjunctiva, named the nictitating membrane; it is commanded by two very peculiarly constructed muscles, which, on exposure to a strong light, are able to bring this semi-transparent fold over the eye, so as to protect it, enabling the organ to bear with ease the full glare of the meridian sun. They are thus supplied with a veil or obscured medium, through which they can look upon that glorious luminary with ease and impunity. It is also found in a rudimental state in some mammalia.

Lachrymal Apparatus.—The tears are secreted in the little distilleries, the lachrymal glands, and poured out upon the inner surface of the upper eyelid by seven or eight tubes; along with the mucus from the conjunctiva, they are spread over the surface of the eye by the movements of the lids. The organs which furnish these secretions sympathize with the conditions of the mind. Under excitement, they are poured out more abundantly, and the brilliancy of the eye is increased under some emotions; the eyelids are at the same time more fully open, the tension of their different muscles is increased, the ball remains fixed, or moves with the quickness of thought, producing a combination which renders the eye one of the most expressive features of the countenance, in connexion with the feelings within.

The two eyelids, when closed, come only in contact with each other at a fine line upon the external part of the margin, leaving a triangular groove between them and the anterior surface of the ball. This groove has an inclination from the temporal angle, downwards and inwards to the nasal angle corresponding with the direction of the level where the eyelids meet, consequently the tears flow down this inclined channel to the inner angle, where, in each lid, there is a small pore by which they are absorbed and conveyed by little tubes into a receptacle from which they are transmitted to the nose. At the internal angle of the eye, a small reddish-coloured body is placed, from its fleshy appearance named the lachrymal carnucle. On minute inspection, a number of short stiff hairs will be found springing from it. It is composed of seven or eight follicles, arranged like a crescent, with the concavity towards the eye. These follicles correspond with those of the margins of the eyelids, so that the series of little crypts is thus completed around the whole circumference of the eye. The colour of the carnucles affords a good index of the state of health: when the general health is vigorous, they are tense, shining, and of a rose colour, while their laxity and paleness indicate debility and disease, thus furnishing one of the numerous tests of health to the physiological physician, whereby he is enabled to estimate the condition of his patient, and detect attempts to impose upon him, whether by the individual himself or by his friends; and to judge also of the condition of those who are unable to give an account of their sufferings and feelings, such as infants, the idiotic, and the insane.

Birds have an abundant secretion of tears; and in addition to the lachrymal glands and follicular crypts, have a gland situated towards the internal angle, named the gland of Harder, which furnishes a thick viscid secretion, poured out by a single duct, opening upon the inner surface of the nictitating membrane. The eye in most birds is closed by the lower lid, which is furnished with a depressor muscle, just as we find that in those animals which possess the greatest mobility in the upper eyelid.a levator is supplied. The ostrich, parrot, owl, and goat-sucker, afford examples in which the upper eyelid is the largest and most moveable.

The conjunctiva forms the lining membrane of the eyelids. As we have already had occasion to mention, it constitutes a part of the gastro-pulmonary mucous membrane, and is continuous with the fine skin of the eyelid. It proceeds backwards to about the middle of the globe, where it is reflected forwards over the transparent anterior surface. It adheres so firmly to the surface of the cornea, that it has been contended by some that it terminates at the margin of that body. But independently of this forming an exception to the otherwise universal law of the skin and mucous membrane, in their various diversities and modifications, being the only tissues exposed immediately to external objects, facts from comparative anatomy do not bear out this opinion. In several reptiles, as in serpents, the skin is continued over the anterior surface of the eye; and when they cast their skins, which they generally do annually, they likewise throw off that portion which covers the eyes. So likewise in fishes the external integument may be observed to pass over the eye, but at the same time it undergoes a modification in its texture, becoming perfectly transparent, so that it offers no impediment to the transmission of the rays of light. The conjunctiva is highly sensitive, an attribute which it owes to the fifth nerve. It manifests irritation by the least contact of external bodies, even in the form of vapour, so that on exposure to the volatile principle, in onions for example, it is excited, and through sympathy the lachrymal glands pour out an abundant flow of tears, and the eyelids are pinched together, the former to wash off, and the latter action to protect it from the irritating cause.

Motions of the Eyeball.—The globe of the eye is placed in the orbit, where, with the exception of the external surface, it is surrounded by fat. It is to be recollected that the fat around the eyeball is contained in comparatively very large cells; that it is of a more fluid nature than that of fat in general; that at the ordinary temperature of the animal this fat is in the fluid state; and that it is less liable to variation in quantity than the same substance in any other part of the body, for we may notice that the sinking of the eyes in their sockets affords the last and most unequivocal evidence of extreme emaciation. The eyeball therefore moves in a fluid medium, fully adequate to give it every necessary support, and at the same time offering the least possible degree of resistance.

The ball of the eye is capable of motion in every direction, though in some directions to a greater extent than in others. Its movements are consequently universal, but for the sake of description they may be resolved into motions on four different axes, or in eight different directions, as the following: In a room we can move the eyes up towards the ceiling or down towards the floor, the eyeball moving on a horizontal axis from the temple to the nose; or we may turn them to the right hand or the left on a vertical axis from above downwards, or on an oblique axis from the inner to the outer angle; and lastly, we can carry them forward so as to cause them to project, or retract them backwards towards the bottom of the sockets. Movements may be effected in these various directions to different degrees of extent. Thus, when we look upon a tall pillar, our eyes may be fixed on the base, the middle, or the top; or when we direct them on a horizontal line, they may be fixed on the right or left extreme, or on any intermediate point, and in like manner upon the other two axes, forwards and backwards, or obliquely inwards and outwards. Moreover, when we reflect that these various movements may be performed with different degrees of velocity, with different degrees of force, and to various degrees of extent, and in all these respects in an infinite degree of combination, we must perceive that the possible combinations and variations of action of which the muscles of the eye are capable, far surpass what the intellect of man is able to appreciate, producing an impression on the mind which can only be indicated by such interjectional expressions as the Psalmist has recourse to—" How wonderful are thy works, O Lord! In wisdom hast thou made them all!"

On reflecting upon all these varieties of movements, and their infinite combinations, the mind is apt to connect them with a complicated apparatus, and to associate them with a multiplicity of machinery accessory to the results. But when the question is put, how are all these varieties of motion performed? and how are these various positions effected? The answer must be, by six little bundles of flesh!

Four of the muscles of the eye arise from the bottom of the orbit, proceed forwards, become tendinous, and are inserted by broad thin tendons into the forepart of the ball, a little posterior to the margin of the transparent cornea, where they are covered merely by the thin mucous membrane or conjunctiva. The white pearly appearance of the eye is caused by these tendons shining through the conjunctiva, and the different tints of the white of the eye depend on the greater or less transparency of the conjunctiva, or it may be tinged with colouring matter deposited in it, as happens in jaundice, where the bile produces a dingy yellow hue.

The muscles receive names according to their actions. Thus, we have the *levator*, raising the eye upwards; the *depressor*, bringing it downwards; the *adductor*, turning it towards the nose; and the *abductor* towards the temple. It is not to be supposed that one muscle alone is engaged in performing any single movement; for example, when the eye is lifted upwards to the top of a pillar, the levator is not the only one called into action; the depressor is at the same time required to moderate the force, and to fix the extent to which the eye is carried. The adductor and abductor also are employed to preserve the motion steady, and prevent vacillation either to the right or left, so that the eye is moved steadily in the required direction with the utmost precision. The levator in this instance merely takes the lead—the other three being in action, in a less degree, but still in action, and in an instant ready to take the lead in any movement in the direction of their individual forces.

By the admirable co-operation of the muscles of the eye, that organ, like the needle of the mariner's compass pointing to the pole, preserves the same relative position with respect to its object, whether the object be in motion or at rest, or whether the body to which it belongs be in motion or at rest. If we fix our eye upon any object, the head may be moved upwards or downwards, to the right or left, the eye all the time keeping perfectly steady. Here we have the eyes fixed, and the orbits moving round them. On the other hand, the head may be kept steady, and the eyes rolled in their sockets in different directions. When the eyes are directed to any object which happens to be moving from right to left, or from left to right, both steadily follow the direction of the object; but the correspondence in the movements of the two eyes does not depend on corresponding muscles, for when both are turned to the right or left, the abductor of the one and the adductor of the other is thrown especially into action. Nor does it depend upon the rays of light falling on corresponding points of the retina, for when the rays enter by the right or left, they fall on those parts of the retina which are respectively on the outer side of one eye, and on the inner side of the other. Neither does it depend on their receiving twigs from the same motor nerve, for the sixth supplies the abductor, while the adductor receives its nerves from the third; it must depend on that power with which the will is endowed, whereby it can command and control the various muscles which are placed under its power, so as to bring them into just association with each other, in order adequately to effect the intended purpose. When the four straight muscles, as they are termed, are simultaneously thrown into action with equal degrees of force, then the eye is retracted backwards towards the bottom of the orbit.

The two other muscles of the ball are called oblique, in consequence of the direction in which they move the eye; and in respect to their relative position the one is termed *superior oblique*, the other *inferior oblique*. The superior oblique, like the four straight muscles, arises from the bottom of the orbit. It proceeds forwards, and becomes tendinous. In connexion with this muscle, we have a very beautiful example of contrivance. Its tendon, when it reaches near to the margin of the orbit, is passed through a little cartilaginous pulley, by which the direction of its action is changed exactly in the same way as we see the direction of the action of a rope changed in machinery, as in the rigging of a ship; but, as may well be supposed, the apparatus in this instance is of the most perfect construction. The little ring of cartilage is of the requisite density, smoothness, and elasticity, a lubricating fluid is furnished to diminish friction, and facilitate motion, and tough ligamentous filaments are attached to regulate the extent of the movements. From the pulley the tendon runs obliquely backwards and towards the internal angle, to be inserted into the ball. When this muscle is thrown into action, the eye is carried in the direction of its tendon forwards, and rolled inwards to the inner angle,—a direction in which the eye is moved when the mind is influenced by passions and emotions; wherefore the superior oblique becomes a muscle of expression.

The inferior oblique arises from the inferior margin of the orbit, external to the lachrymal sac. It proceeds towards the bottom of the orbit, being under the ball, and is inserted into the ball near the external angle. In action it pulls the eyeball forwards, and rolls it obliquely outwards to the temple. When the two oblique muscles are thrown into action with equal degrees of force, the eye is neither rolled inwards nor outwards, but is steadily carried forwards.

From the above view of the motions of the eye, and of the muscles by which they are effected, it appears that the globe of the eye moves in eight cardinal directions: by the four straight muscles it is moved upwards, downwards, to the right and to the left, each of these movements being effected by an appropriate muscle; that when these four act together, it is drawn backwards towards the bottom of the orbit, moving steadily in the diagonal between their different forces; that the eye is moved in the other three directions by the two oblique muscles, each producing a motion peculiar to itself, whereby the eyeball is rolled obliquely inwards by the one, and outwards by the other, while, by the combined action of both, it is brought forwards. As far as the muscles of the eye are voluntary, their action in the various movements necessarily requires the exercise of volition, or in other words, the mind must first determine on a purpose, and then issue its command along the nerve to the muscle thereby called into action. Accordingly, every movement of the eye, however slight, must be preceded by an act of the will, and accompanied with consciousness, although the determination of the purpose, the conveyance of the command, and the completion of the motion, are performed in succession, with such rapidity that they appear only as one act. When an officer stands in the front of his regiment drawn up in line, he partly becomes aware of the relative position of each individual, in consequence of the muscular effort necessary to place the eye upon each; and when we look upon different heights of a tall pillar, the eye requires to be shifted so as to be directed to every point upon which it is fixed. In like manner, by the adjustment of the eye through the medium of the muscles do we become in some measure aware of the relative distances of different objects, by instituting a comparison between them and the various intervening objects. In consequence, therefore, of the voluntary effort required in placing the eye in these different circumstances, we are informed of the various relative positions and distances of bodies, independently of the various intensities with which they may be illuminated.

In man, apes, monkeys, and bats, among mammalia, and in owls, in the class of birds, both eyes look forwards, and are capable of being fixed upon, and of receiving impressions from the same object simultaneously. In order to effect this, it is necessary that the axes of both eyes be brought parallel with each other, so that the rays coming from the same points of an object may fall upon the central point of each retina, the seat of distinct vision, where these nervous membranes appear especially to sympathize with each other. When the rays of light from any object fall upon these corresponding points, the object is seen single. Single vision with two eyes, therefore, requires voluntary muscular action, in order to effect the proper adjustment of the eyes, that the requisite degree of convergence of their axes may be produced. Where the object is near, as at the tip of the nose, this convergence is very considerable,—becoming less as the object is removed to a greater distance. To bring the two eyes into just accordance with each other, and to maintain the proper degree of convergence, some experience is necessary; for if they are not accurately adjusted, the object appears double. If an object is held up in one hand close to the tip of the nose, and another object with the other hand at the distance of ten or twelve inches in the same line, on fixing both eyes upon the near object, the distant one will appear double; but if they are fixed upon the distant object, then the near one appears double.

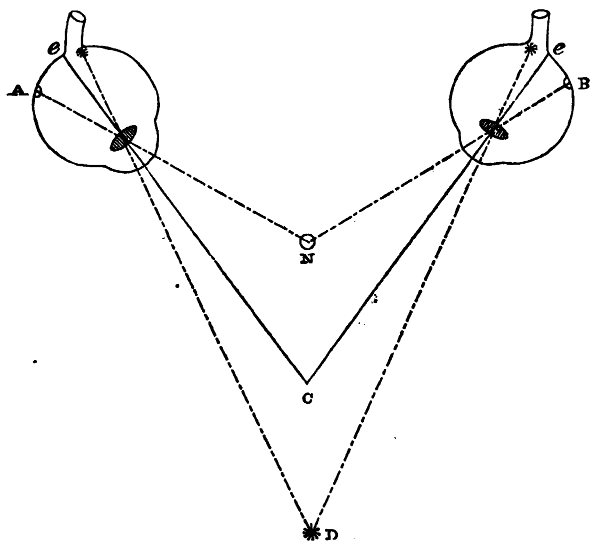

FIG. 25.

The annexed figure may illustrate this, and it will be still better understood when the retina has been described. There is a space at the bottom of the eye, which is the centre of distinct vision, as at *e e* in the eyes A and B. Thus the rays from an object at C will fall upon the centre of distinct vision at *e e*, and be distinctly seen. Unless the rays from any object fall upon this in both eyes, it will appear double, so that when the attention is fixed on the distant object, as at D, then the near object at N is seen double, and conversely. Thus the eyes require to be adjusted to each distance, that single vision may be effected with two eyes.

There can be little doubt that the necessary dexterity in the use of the muscles employed in these movements is only acquired gradually by experience, in the same manner as the requisite command and facility of using our other voluntary muscles is only obtained by education, and after repeated trials and failures, as the use of the limbs in walking, the employment of the hands for the various purposes of the arts, the exercise of the organs of speech, and so forth. The vague and indefinite expression of the eyes of infants is a proof of this. Any one carefully noticing the eyes of a young infant, will perceive that they are never fixed in such a manner as to effect the proper convergence of their axes upon one object; consequently single vision with two eyes does not take place at this period of life, nor until experience has given the necessary dexterity. The drunkard loses the necessary control over these muscles, and therefore sees double, just as he stammers in his speech and staggers in his walk. Although the adjustment of the two eyes be thus difficult, in somewhat the same proportion is the accuracy obtained as to the relative position of different objects; hence the greater facility of threading a needle, for example, with both eyes than with one, and hence, too, the experienced archer adjusts the direction of his arrow with both eyes, while the inexperienced marksman conceives it better to have recourse to one, and consequently the aim is not so certain. In by far the greater number of mammalia, birds, reptiles, and fishes, the eyes are so placed on each side that they cannot be brought to bear upon the same object at the same time; their lateral position, however, has the effect of vastly extending their sphere of vision, and the precision with which several of them mark the relative position of objects is sufficiently evinced by the accuracy with which many birds will pounce upon their prey from great heights in the air, notwithstanding their knowledge of its position having been obtained from a single eye.

Besides the six muscles by which the motions of the eye are effected in man, the great majority of mammalia and birds are furnished with a seventh, named the *suspensory*. This muscle is situated at the back part of the eyeball, arises from the bottom of the orbit surrounding the optic nerve, and is implanted in the ball posterior to the other muscles. It is composed of several bundles, so distinct that they may be considered as forming so many distinct muscles, each capable of performing separate and independent movements; at the sametime none of these bundles, either independently or conjointly, can place the eye in any direction into which it may not be brought by the straight muscles of the human eye, or of those animals in which it is present. From the mode of its insertion the extent of the motions effected by it must be more limited than those which result from the action of the straight muscles. The name, suspensory, would lead to the inference that its use is to suspend the eye in its socket when the head is in the dependent posture; but a ligament would have answered the intention much better, as it would have accomplished the end sufficiently, and at the same time would not have been liable to the fatigue to which muscular fibre is exposed. The action of this muscle, alternating with that of the straight, may afford both muscles an interval of rest, and by their combined action a more just idea of the relative position of objects may be obtained, whereby the same result may arise as from the exercise of the muscles of two eyes.

In man, when the motions of the eyes are too limited for the sphere of vision that may at the time be required, it may be instantly extended by the motions of the head, and if these are still too confined, the whole body may be turned round on the heels, as on a pivot, so as to bring the whole horizon in succession upon the field of distinct vision; thus by the motions of the eye, with the co-operation of the motions of the head, neck, and trunk in various directions, the canopy of the heavens above, and the surface of the earth beneath, may be viewed in a portion of time so minute, that what is successive appears instantaneous. In the lower animals, the lateral situation of the eyes effect the same purpose, and in many of them, especially in birds, the flexibility of the neck enables them to place the eye in the desired position in an instant. The great majority of reptiles are placed prone upon the surface of the ground, and require their eyes to be directed upwards, so that their position enables them at once to take in the necessary extent of the sphere of vision, without the intervention of muscles. The eyes in these animals are therefore fixed, and where an extension of the sphere becomes desirable, it is effected by the motions of the head. The chameleon, which remains perfectly motionless, lest it should alarm its prey before it comes within the reach of its long prehensile tongue, has an eye supported on a pivot, on which it turns in different directions. The whole eye is covered with integument, of precisely the same colour with the rest of the animal, with the exception of the pupil, so that the motions can only be noticed on the closest inspection, consequently no alarm is given to the unwary insect till it comes within the reach of its tongue, when it is too late, as that instrument is darted out with a quickness which often escapes the eye of the bystander, and he is aware of the insect being removed only by its disappearance. In lobsters and crabs the eye is placed at the extremity of a long tube, which can be moved in various directions, extended or withdrawn, whereby the inconvenience which might have arisen from their rigid and inflexible bodies is obviated. Spiders, like the chameleon, require patiently to wait and seize their prey by stratagem. The slightest movement on their part might give the alarm. They remain therefore perfectly still and motionless, till the heedless fly is entangled in their net, when they instantly issue forth and destroy it. Although they appear in the midst of the web inattentive, nevertheless, Argus-like, they have an eye in every direction, for nature has furnished them with from six to fourteen eyes, according to their tribes, that they may have one on every point, and take in an extensive sphere of vision, without the necessity for motion, which would have been incompatible with the means by which they gain their subsistence. The greater number of insects are furnished with two kinds of eyes, one of which is termed compound, from being composed of several hexagonal facets, each of which is a distinct eye in itself. These facets vary in their size, and from their position are enabled to receive the rays coming from different directions. Hooke, in his Micrographia, has the following observations on the compound eyes of the grey drone-fly :—" These rows were so disposed that there was no quarter visible from his head that there were not some of these hemispheres directed against, so that a fly may be truly said to have an *eye every way*, and to be really *circumspect*. And it was further observable, that that way where the trunk of his body did hinder his prospect, these *protuberances* were elevated, as it were, above the plane of his shoulders and back, so that he was able to see backwards also over his back.

" In living flies I have observed, that when any small mote or dust which flies up and down the air chances to light on any part of these knobs, as it is sure to stick firmly to it and not fall, though through the *microscope* it appears like a large stone or stick (which one would admire, especially since it is noways probable that there is any wet or glutinous matter upon these *hemispheres*, but I hope I shall render the reason in another place), so the fly presently makes use of its two fore-feet, instead of eyelids, with which, as with two brooms or brushes, they being all bestuck with bristles, he often sweeps or brushes off whatever hinders the prospect of any of his *hemispheres*, and then, to free his legs from that dirt, he rubs them one against another; does cleanse them in the same manner I have observed those that card wool to cleanse their cards, by placing their cards so as the teeth of both look the same way, and then rubbing them one against the other. In the very same manner do they brush and cleanse their bodies and wings, as I shall by and by shew. Other creatures have other contrivances for the cleansing and clearing their eyes.

"The number of the *pearls* or *hemispheres* in the clusters of this fly was near 14,000, which I judged by numbering certain rows of them several ways, and casting up the whole contents, accounting each cluster to contain about 7000 pearls, 3000 of which were about a size, and consequently the rows not so thick, and the 4000 I accounted to be the number of the smaller pearls next the feet and *proboscis*. Other animals I observed to have a greater number, as the *dragon-fly* or *adderbolt*, and others to have a much less company, as an *ant*, &c., and several other small flies and insects."

Some species of butterflies have facets amounting to the number of 34,650. In these compound eyes each facet consists of a hard transparent lenticular body, through which the rays of light pass, to reach a corresponding division of the optic nerve, so that each facet is composed of a very dense cornea for collecting and transmitting the rays, and a bundle of nervous matter for receiving their impression, each facet thus forming a complete eye in itself. Exposed as these animals are to the atmosphere, fluids would soon have been dissipated by evaporation. Their eyes are therefore constructed upon principles which do not require fluids, and the various adaptations which result from the modifications the humours undergo in the higher tribes of animals are compensated for by the number of eyes with which they are furnished, each facet being fitted to see objects at a certain distance; and as the distances vary, a facet is applied in accordance to it, being furnished with a lens of the adequate size and convexity. The facets being immoveable, their number also compensates for the want of motion, so that they have an eye in most directions at once. The variety, extent, and combination of the motions of the eye, as well as the facility with which the humours accommodate themselves to varying circumstances in the higher classes of animals, produce an infinitely greater number of adaptations to distances, positions, and degrees of illumination, than result from the thousands of eyes with which these insects are furnished. From what has now been mentioned, it appears that, with respect to motion, situation, and number, the eyes have reference to the form and structure of the animal, as these again have a reference in their turn to various functions, relations, and circumstances, which the animal more accurately discovers by instinct than the physiologist by his profound and laborious researches.

The peculiar defective state termed squinting arises from several causes. A very common one is unequal power in the eyes, which induces the individual to use the stronger one, the weaker being left to wander irregularly at random, though generally brought under the influence of the superior oblique, whereby the countenance appears to have an expression of feelings which the person by no means entertains at the time. Occasionally the individual is unconscious of this inequality, until it is pointed out to him by desiring him to close the more perfect eye and employ the weaker, so as to institute a comparison between them. One means whereby this deformity may be obviated is by covering the stronger eye, and for some time using the other, till their strength be reduced to an equality, when the squinting disappears. In other cases the distortion arises from loss of power in one or other of the muscles, and for the most part will be found irremediable. When a person is in a deep reverie, where the effort necessary to preserve the parallelism between the two eyes is suspended, squinting takes place; and when he is roused from this state of mental rumination, the eyes may be seen to start again into concordance. The same occurs during sleep, when volition is entirely suspended; and it forms a symptom indicative of the condition to which the system is reduced by narcotic poisons. Sometimes squinting depends on the condition of the brain, and points out the state of the internal parts; in this way it frequently happens in water in the head, or apoplectic diseases.

Globe of the Eye.—The eyeball consists of a number of membranes termed coats, enclosing certain humours, through which the rays of light are transmitted and modified before they fall upon the nervous screen, on which they make their impression. Each of these must be studied individually before we are prepared fairly to estimate the result of the action of the whole.

The Sclerotic Coat, so named from its firmness and density, constitutes about four-fifths of the globe of the eye, the remaining fifth being formed of the transparent cornea. It is composed of a number of fibres, intricately interwoven with each other; between them are disposed several irregular-shaped plates, which contribute to its consistency. Its colour is bluish white; anteriorly it is thicker and denser where the tendons of the muscles are implanted into it. Neither blood-vessels nor nerves can be traced to their termination in it, though many of both perforate it in their passage to the internal parts. Upon the whole, it must be held as possessing only a low degree of vitality, and therefore better fitted for the purposes of defending the delicate internal parts, and affording a fixed attachment to the muscles. In the whale tribe it is upwards of an inch in thickness at the back part, yet a whale seventy or eighty feet in length has an eye the interior of which is not more capacious than that of a bullock. In birds, on the other hand, the anterior part is much thicker and stronger, and in several composed of a series of bony plates, forming a collar around the anterior surface of the ball. The purposes served by these modifications of structure have not been ascertained, though no doubt they are the best fitted to the circumstances of the animals in which each obtains.

The Cornea is the term applied to the anterior transparent portion of the ball. It is a segment of a smaller sphere than that of the sclerotica. In the human subject it is nearly circular; its convexity varies in different individuals and in different ages. It is received into a circular groove in the anterior margin of the sclerotica, in the same way as the watch-glass is inserted into the case. The cornea is somewhat thicker than the sclerotica, and composed of six concentric plates, separable from each other without much difficulty, after a little maceration. A small quantity of transparent fluid may be squeezed out from between its plates; but its blood-vessels are so exceedingly minute that they totally exclude the colouring particles of the blood, so long as it retains its organization. When affected with inflammation it loses its transparency, whereby more or less complete blindness results from the obstruction to the passage of light.

Between the sclerotic coat and cornea there is placed a ring, circle, or ligament, generally known by the name of *ciliary ligament;* besides the cornea and sclerotica, it is connected with the iris and choroid coat, especially with the latter. It constitutes a good point of reference when speaking of the relative position of other parts.

The Choroid Coat is formed principally of a tissue of blood-vessels and nerves, with a delicate cellular membrane interlaced through them. Its great vascularity has caused it to be likened to a vascular membrane, investing the fœtus in the womb, termed chorion; hence the origin of its name. It lies immediately in contact with the internal surface of the sclerotica, commencing at the optic nerve behind, for the passage of which there is a hole in it. It proceeds forwards till it reaches the ciliary ligament, where it is folded into a number of plaits like the ruffle of a shirt; these collectively form a zone or belt, which is placed immediately behind the iris, surrounding the margin of the crystalline lens like a collar, and fringed with little projections or processes which float in the watery humour. Its great vascularity, and the numerous nerves distributed upon it, chiefly derived from the fifth nerve, indicate its high sensibility; and from its close proximity to and intimate relation with the retina, it becomes directly connected with sight. Although the nerves distributed on the choroid are incapable of transmitting such impressions as properly produce sight, yet they are highly sensitive to the rays of light, and constitute the channels by which painful sensations are conveyed to the mind, from exposure of the eye to the intense light of the meridian sun for example. In this view the choroid may be considered as the sensitive guardian of the retina; as that nerve can only convey specific impressions, it was necessary that it should be associated with a structure which might give warning on the approach of danger.

The vessels of the choroid secrete a dark-coloured matter, consisting of globules, and named *black pigment*. From the external surface this pigment is easily brushed off, though not so readily from the internal, where it is protected by a delicate membranous expansion. The dark colouring matter is well fitted for absorbing the superfluous and scattered rays of light. In some animals a portion of the internal surface of the choroid, instead of being furnished with dark pigment, is supplied with covering of a bright metallic lustre named *tapetum*. It exists in the horse, dog, and many other animals; and when they are placed in an obscure light, produces a reflection of light which gives their eyes that remarkable brilliancy that makes many suppose that they flash fire.

The number and size of the vessels of the choroid are much greater than what would be requisite merely for the nourishment of this membrane and the secretion of the dark pigment. The arteries, by their frequent communications with each other, present a beautiful appearance of network, and the veins are so disposed as to form numerous whorls. Both of these arrangements are well adapted for admitting of congestion, and readily accommodate themselves to varying quantities of blood in each set of vessels. Another circumstance affecting the circulation of blood within the eye arises from the sclerotica and cornea being of sufficient firmness and strength to enable them to resist the influence of atmospheric pressure; consequently the circulation in the interior of the eye is in somewhat similar condition to that within the skull, the quantity of blood in the vessels remaining the same under every variety of atmospheric pressure. Neither can it be diminished by blood-letting and other means of depletion, although the force with which it is transmitted may be lessened. Accordingly we find that in inflammation of the interior of the eye, leeching, cupping, and even general blood-letting, have not that impression in subduing the symptoms that is usually produced by them.

The Iris.—The colour of the eye depends upon that of a curtain or partition which divides the interior of the eye into two unequal portions, termed chambers. The colour of this curtain varies in different individuals, being dark-brown or black, light-grey, blue, and several shades and combinations of these. The variety of colour is still greater in the different species of the lower animals, and particularly in birds, in which it exhibits hues as various as the rainbow, whence in fact its name is derived. In the centre of the iris a dark spot is observed, commonly called the *star* of the eye. This is a hole through which the dark pigment of the choroid coat is seen. If we look into the eye of another, or on our own reflected in a mirror, we shall perceive a little image of our own face, like a very minute child or pupil, consequently this hole has received the name of *pupil.* The iris is attached at its greater circumference to the ciliary ligament, the smaller forming the margin of the pupil. The anterior surface presents two concentric bands; the interior surrounds the margin of the pupil, and is of a darker colour than the exterior broader belt. Upon closely inspecting the surface of the iris several undulations or folds may be observed radiating from the ciliary ligament towards the pupil, on approaching which they divide, and are interwoven with each other. The lines marked upon the iris have been imagined to represent letters and other characters. A remarkable example of this occurred in the south of Scotland a few years ago, where an illegitimate child was born. The man who had been indicated by the mother having denied the paternity, the charge was brought home to him to the entire satisfaction of the credulous and superstitious, by his name being written upon the child's iris, with the year of its birth, 1819. It was afterwards carried about for several years for public exhibition, when we had an opportunity of examining the eye, but failed in tracing the letters or figures on the iris, which was of a light-blue. We have no doubt, however, that by a little aid from creative fancy, they might have been perceived, just as castles, towers, and pinnacles are conjured up amidst the dying embers.

The posterior surface that looks towards the ciliary folds is furnished with dark pigment, and this shining through the iris imparts to it the colour characteristic of the individual. In albinos of the human race, and in the lower animals, the dark pigment is wanting both in the choroid coat and this membrane, and these parts being very vascular, the blood is seen imparting a red colour to the eye. From the deficiency of the dark pigment, albinos cannot tolerate a strong light, such as at noon-day, while they are said to enjoy vision very perfectly during the obscurity of night. Indeed, persons differ considerably as to their powers of vision, in strong and obscure light. Those possessing the power of seeing distinctly under the former condition are said to have diurnal, and the latter nocturnal sight. According to the habits of various animals, we perceive them enjoying different degrees of these, as the falcon tribe on the one hand, and owls on the other.

The iris consists of three layers, covered by a serous membrane. The anterior layer is composed of circular fibres, which contract so as to diminish the size of the pupil. The posterior layer, on the other hand, is formed of radiating fibres, arising from the ciliary ligament, and running towards the margin of the pupil. These, when thrown into action, enlarge the pupil. The middle layer is composed of a net-work of blood-vessels, along with which nervous twigs are plentifully distributed. It may be mentioned, however, that the movements of the iris are attributed by some to a greater or less accumulation of blood in the vascular net-works, of which there are two, of different diameters—the larger around the margin of the ciliary ligament, the smaller surrounding the margin of the pupil. This opinion has been taken up from the impossibility of clearly demonstrating muscular fibre in the tissue of this organ, though at the sametime many motions are performed in animals by textures widely different from what is usually held as proper muscular fibre, and their muscularity is not disputed. Those who deny the muscularity of the iris cite the experiment of transfixing it with a needle, when no motion can be perceived; but in this case both fibres must be irritated, and their contractions consequently neutralize each other. On the other hand, when the experiment is so conducted as to irritate merely the anterior layer of circular fibres, the contraction is distinctly perceptible.

The iris by its movements regulates the quantity of light passing through the pupil. During sleep, the pupil will be found in an intermediate state, and when the person is awakened in an obscure light, and begins to exercise his sight, the pupil will be seen to contract. Again, when a strong light is thrown upon the eye, it very distinctly contracts so as to diminish the quantity of light admitted into the interior of the eye, the intercepted rays being either absorbed by the pigment, or reflected back again through the cornea; those rays alone which pass through the pupil contributing to vision by striking against the retina. If a person hold a candle close to the eye of another, the pupil will be observed much contracted, and as the candle is withdrawn it will gradually dilate, showing how admirably this little curtain is constructed and endowed for the purposes of its creation. The anterior circular fibres which are chiefly to be engaged in the regulation of the pupil in respect to light, are so situated as at once to receive their impression, while the radial fibres are placed behind, being called into action principally in accordance with the condition of the interior organs.

It also contributes to the adaptation of the eye to near and distant, to large and minute objects. A curious experiment may here be mentioned, that will serve to illustrate this:—If a small object, such as a hair or a fine needle, be held before one eye, while the other is closed, so that the bright light from the window, or the flame of a candle, falls upon the object; or if it be a needle, the back of the person may be turned upon the light, and the bright reflection received by the eye; when the object is placed at the distance of fifteen or eighteen inches, that is, at the point of distinct vision, it will be seen single; but when carried a little nearer it will appear double, treble, or quadruple, and so on as the distance is varied. The best way of performing the experiment is to take a parallel ruler and open it slightly, so as to afford a small linear aperture; on holding it up between the eye and the light, alternate bright and dark lines will be seen according to the distance at which it is held within the point of distinct vision. This curious multiplication of the image of an object has been accounted for by what Newton has termed fits of easy refraction and fits of easy reflection. Now, if the eye of the person making the experiment be watched as he approximates the object to his eye, and is intensely engaged in counting the number of images, the pupil will be seen contracted to a minute point. Or if we hold up before a person a sheet of white paper on which minute characters are traced, first directing him to place his eyes fixedly on the paper, then marking the condition of the pupil, we next desire him to endeavour to make out the characters; when he attempts to do this, the pupil will be seen to contract, in order to fit the eye for the examination of minute objects. By this contraction of the pupil the more divergent rays of light which pass through the cornea are prevented from entering into the posterior chamber, and consequently cannot pass through the margin of the lens, where they could not have been brought to a correct focus on the retina. In this way spherical aberration is obviated.

The iris derives its nerves from the lenticular ganglion of the fifth, from the third or motor nerve of the eye, and filaments accompanying its numerous blood-vessels from the sympathetic and respiratory nerves. Its being furnished with twigs from the third is confirmatory of its muscularity, and the filaments from the other sources explain its sensibility and the sympathy it displays with the condition of other parts. Where blindness arises from loss of power in the retina, occasionally the iris displays no mobility in accordance with different degrees of light, while in other cases it is but little impaired. Irritation of the nostrils causes contraction of the iris, which is easily accounted for by the nervous connexions that have been already explained. The iris especially sympathizes with the condition of the brain and nervous system in general. Where susceptibility to impressions is impaired, either by narcotic poisons or by disease, the condition of the pupil affords valuable information to the medical practitioner as to the state of his patient, in the various phases the disease may present during its progress. The deadly nightshade has obtained the name of *Belladona*, or beautiful lady, from the paleness its use produces, and from causing a dilatation of the pupil, and therefore a dark eye; the names *Atropa* and deadly nightshade are however the more applicable terms, from its very dangerous qualities.

In the lower animals the iris presents great diversities, not only in its colour, but in its mobility, and in the form of its pupil. In birds, especially in owls, the motions are free, conspicuous, and evidently voluntary; the same holds good in the cat tribe. In reptiles its motions are obscure, and in fishes altogether imperceptible. In ruminants, in the horse, the marmot, and in the whale tribe, the pupil is elongated transversely, so that a greater number of the lateral rays receive entrance into the inner chamber from the upper margin. In the horse a small square curtain hangs down, which must intercept a great part of the rays coming from above. It is also elongated transversely in owls, the goose, and the dove among birds. In the cat tribe, as in the domestic cat, the lion, the tiger, leopard, and so forth, it is elongated vertically, as it is also in the crocodile. These animals have, therefore, so far as the pupil is concerned, a more extensive sphere of vision, and a greater number of rays admitted from above downwards than in the lateral directions, and their habits accord with this conformation in watching their prey, which is very generally placed above them, and more in front than to either side, while timid animals, such as ruminants, have to guard against the insidious approach of enemies while quietly browzing in the fields;

their pupil accordingly admits freely of the rays coming laterally.

In the fœtal state the pupil is closed by a membrane till about the seventh month, when it disappears. In those animals which are born blind, and continue so for some time after birth, such as the dog, cat, and so forth, the eyelids are united by the conjunctiva passing between them, so as to form a mucous sac, shut in all directions excepting along the lachrymal canals towards the nose, an arrangement which obtains through life in reptiles. In these animals thus born blind, the pupillary membrane remains till the eyes are opened. It has been suggested that the use of the pupillary membrane is for the purpose of keeping the pupil open during the formation of the different parts—an explanation which is by no means satisfactory, as it would imply imperfection and deficiency in resources, neither of which ever exist in organized structures. We may rest assured that all the various modifications of structures are the best possible in every individual case, though we may fail in ascertaining the manner in which they conduce to the purposes intended, or even in comprehending the end of their formation. It therefore better becomes us at once to confess our ignorance, than idly to hazard an explanation which may be far from the truth, and tend more to the retardation than the advancement of sound knowledge.

We have next to consider the transparent parts of the eye, through which the rays of light pass before they reach the retina to depict the image, whereby the impression of the external objects is received, subsequently to be conveyed to the seat of perception, the brain. The cornea, one of these, we have already described, leaving for consideration three substances termed humours:—One of these, the *aqueous humour*, differs little from transparent water, excepting in holding in solution some of the salts of the blood, and a trace of albumen. The second is curiously organized, of a lenticular shape, and, from its resemblance to rock crystal, named the *crystalline lens*. The third, from presenting the appearance of a mass of melted glass, has received the name of *vitreous humour*.

The Aqueous Humour is furnished by a thin delicate transparent web, covering the internal surface of the cornea, and the anterior surface of the iris. From its structure and use, this web ranks under the class of serous membranes, having the peculiarity of being perforated at the pupil. Although previous to the removal of the pupillary membrane it constitutes a complete shut sac, the disappearance of that partition leaves a hole in it. The watery humour which it secretes fills not only the anterior chamber between the cornea and the iris, but also the posterior chamber between the iris and the lens, and is very rapidly renewed after being evacuated, as it occasionally is in surgical operations. It is derived chiefly from the exhalation of the vessels of the iris, and may possibly contribute by its varying quantity to the adjustment of the eye to different sizes and distances of objects, which is probably a conjoint result of the action of several parts of the complicated machinery of the eye, and not merely dependent upon the condition of any one part. This adjustment of the eye to near and distant objects, to large and minute, can scarcely be altogether the consequence of muscular movements, as it requires some time to be adequately adapted to the distance, or to the size, which would at once have promptly been effected had it depended on muscular contractility alone, as we see to be the case in placing the eye in different positions. On fixing it on a distant object, as on a ship far at sea, it takes some time before we can well make it out, as it also does before we can satisfactorily ascertain the texture or conformation of a very minute object. These changes, necessary to the proper arrangement of the eye, in order to fit it to different purposes, appear to be in accordance with the more gradual results of vascular alterations, although these may only constitute one part of the requisite adjustment. The increase and diminution of the aqueous humour are capable of affecting, to a certain extent, the relative position of the lens. By the former the lens may be pressed backwards near to the retina, and by the latter again allowed to move forward nearer the pupil. Where the accumulation of aqueous fluid is considerable, it alters also the form and condition of the cornea, rendering it more convex, while, if it take place to any considerable extent, the pressure produces opacity of the substance, thereby causing blindness. This sometimes occurs with horses that have been fed during the winter in the stable on dry food, either placed on a level with the head, or considerably above it. On turning them out in spring to the green pasture, where there is not only a change from dry to succulent diet, but also in the position of the head in collecting the food, congestion of aqueous humour is apt to occur to such an extent as to produce temporary blindness.

The Crystalline Lens is placed immediately behind the pupil, and is bathed anteriorly by the aqueous humour. It constitutes a doubly convex lens, perfectly transparent. The posterior surface is more convex than the anterior, and it approaches nearer to a sphere in infancy than in adult age. The lens is enclosed in a capsule, which forms a shut sac, firmer and denser anteriorly than posteriorly, and also transparent. The capsule of the lens is itself invested by an extension of the delicate web which surrounds the vitreous humour, and known by the name of *hyaloid membrane*. This membrane, on reaching the margin of the lens, divides into two layers—the one passing over the front of the capsule, the other covering it posteriorly. Where they separate, a small triangular canal is left, running round the circumference of the lens.

When the crystalline lens is first removed from its capsule, it appears like a mass of transparent crystal, without trace of any special organization. Towards the surface it is soft and pulpy, becoming more and more dense and consistent towards the centre. Its density is also found to be in the direct ratio of the age, it being soft in the young, and firm and dense in the old. It consists principally of albumen; consequently, when exposed to heat, as by putting it into boiling water, it is hardened, and becomes milk-white, or of an opal colour. Alcohol, acids, and several metallic salts, produce a similar effect. When examined in this state it will be found to be very curiously organized, especially towards the centre, for the soft surface, from its delicacy, does not display any particular organic arrangement. The firmer central mass presents a number of concentric plates or lamellæ. Two thousand of these have been counted, increasing in their density towards the centre. Each layer consists of an infinite number of exceedingly minute filaments, wound round in different directions, from various centres. The arrangement of these fibres differs in various animals, but remains uniform in every individual of the same species.

In fishes the lens is almost completely spherical. It is less so in reptiles, and becomes more flattened in birds and mammalia. In those of the latter class, whose vision is adapted both for air and water, as seals and whales, the lens is of greater convexity than in those which employ their eyes in the former medium only.

The lens, or its capsule, or both at the same time, occasionally become opaque, producing partial or complete obstruction to the transmission of the rays of light, and forming the disease named *cataract*. The removal of the diseased lens from the sphere of vision frequently produces a cure of the accompanying blindness, when the space occupied by the lens is filled up by aqueous humour.

The Vitreous Humour is a glairy transparent fluid, contained in the cells of an equally transparent membrane, named the hyaloid. This delicate web forms numerous cells, which communicate with each other, so that if we puncture it, the somewhat viscid fluid with which they are filled will in time escape, though but slowly, from the intricacy of the cellular structure. When first removed from a fresh eye, the vitreous humour presents a globular shape, with a depression in front, for the reception of the posterior hemisphere of the lens. At first sight it appears to possess a consistency equal to the white of an egg, but in reality it is much less so, the appearance arising from the fluid being retained in the cells of the hyaloid.

This humour occupies two-thirds of the cavity of the eyeball, and serves principally to afford a surface for the extension of the expanded retina, to keep the lens at the requisite distance, and to transmit the rays of light.

Retina.—The retina is so named from presenting an interlacement of tissue like a net-work. It consists of two layers; the one, embracing the vitreous humour, is composed of a net-work of blood-vessels; the other, contiguous to the choroid coat, consists of soft medullary nervous matter. It is, however, not in immediate contact with the choroid, for there is interposed between them an exceedingly delicate film, corresponding to a neurilema, named Jacob's membrane. In the living body the retina is perfectly transparent, and remains so after death, so long as the vital warmth continues, but afterwards becomes of a pale milky colour, and rapidly hastens into decomposition. If the blood-vessels be filled with injection, and the retina macerated for a day or two, the nervous layer may be removed with a gentle stream of water, leaving the vascular layer behind.

The retina is continuous with the optic nerve, though different from it in texture and consistence; if, therefore, it is held as an expansion of that nerve, it must be admitted at the same time that a considerable change in structure takes place along with the expansion. It proceeds forwards, along the internal surface of the choroid, till it reaches the commencement of the ciliary folds, where it forms a somewhat thickened ring, from which, according to some, it is extended as a very thin nervous film over these folds to the margin of the lens, while others contend for its termination at the rim.

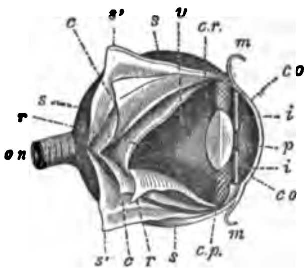

Fig. 26.

The accompanying engraving will convey an idea of the parts now described: *m m* are reflections of the mucous membrane, covering the front of the eye; *c o c o* the cornea; *i i* the iris, with the hole, the pupil, in its centre, marked *p*; *c p* are the ciliary folds; *c r* the crystalline lens; *v* the vitreous humour; *s s s* the sclerotic coat; *s' s'* the same turned back; *c c* the choroid coat; *o n* the optic nerve; and *r r* the retina.

From the transparency of the retina, the rays of light must pass through it, and depict the image behind it on the choroid. But, however that may be, this delicate web is admitted to be most essential to vision, to which the retina, indeed the whole of the rest of the apparatus, may be considered as merely subsidiary. The nervous layer is that which is directly connected with vision. By proper management of the following experiment, the blood-vessels of the vascular layer may be seen by the eye, or rather nervous layer, to which they belong. Having closed the left eye with the left hand, take a candle in the right hand, and hold it about two or three inches from the right temple, at the same time keeping the eye of that side steadily looking forwards; then move the candle slowly upwards and downwards. In the course of three or four movements the blood-vessels of the vascular layer of the retina will come into view greatly enlarged, and presenting a beautiful example of vascular distribution.

The optic nerve, on reaching the sclerotic coat, is contracted; it then penetrates that investment and the choroid, and enters the interior of the eye, not in the centre of the sphere, but about two lines from that centre, on the side next the nose, a little below the transverse axis. In the centre of this point an artery enters, which is probably the cause of the insensibility to the impression of light at that spot, as may be shewn by the following experiment. Place on a wall three pieces of paper, on a horizontal line, parallel with the eyes, and about two feet apart; the middle piece may be placed half an inch below the two lateral. Stand opposite the middle paper, three feet from the wall, close the left eye, and fix the right on the paper on the left, the three papers at this distance will be seen. Now, retire slowly backwards, and at the distance of eight or ten feet the middle paper will disappear, as if suddenly removed, and the space it occupied will seem of the same colour as the rest of the wall. On retiring still further back, it will again come into view. In this instance the rays of light from the middle paper, at the distance where it vanishes, will be found to fall exactly upon the centre of the optic nerve, where it enters, that is, where the central artery of the retina is placed.

Directly opposite the pupil, or in the exact axis of the eye, may be observed a yellowish spot, with a small hole in its centre; by the removal of Jacob's membrane this spot is more easily detected. It is by no means general in the animal kingdom, having been as yet detected only in man, apes, and a few reptiles: its use is altogether unknown; for though it exactly corresponds to the point of the retina where the most distinct vision takes place, still in those animals which enjoy sight even more perfectly than man does, it cannot be detected.

When we look upon an extensive landscape, a corresponding picture is depicted on the retina, and the mind receives a general impression of the scene. If any object attracts particular attention, the eyes are especially directed to it, and the rays coming from that object now impinge against the centre of the retina, on the point of distinct vision, and a more clear and vivid perception is obtained, constituting distinct or direct vision.

The rays falling upon the rest of the retina, although they do not impart distinct vision, still make a sufficient impression to communicate a general conception of the relative situation, appearance and distance of objects, and the rapidity with which the eye moves from one point to another of the landscape readily compensates for any inconvenience which might arise from this source. Sir David Brewster has the following remarks upon indirect vision, which are interesting:—He says, "In making some experiments on the indistinctness of vision at a distance from the axis of the eye, I was led to observe a very remarkable peculiarity of oblique vision. If we shut one eye, and direct the other to any fixed point, such as the head of a pin, we shall see indistinctly all other objects within the sphere of vision. Let one of these objects thus seen indistinctly be a stripe of white paper, or a pen, lying upon a green cloth. Then after a short time the stripe of paper, or the pen, will disappear altogether, as if it were entirely removed; the impression of the green cloth upon the surrounding parts of the eye extending itself over the part of the retina which the image of the pen occupied. In a short time the vanished image will re-appear, and again vanish. When both eyes are open, the very same effect takes place, but not so readily as with one eye. If the object seen indistinctly is a black stripe on a white ground, it will vanish in a similar manner. When the object seen obliquely is luminous, such as a candle, it will never vanish entirely, unless its light is much weakened, by being placed at a great distance; but it swells and contracts, and is encircled with a nebulous halo, so that the luminous impressions must extend themselves to adjacent parts in the retina which are not influenced by the light itself."

Indirect vision would thus appear not only to be less distinct than direct vision, but also to be incapable of sustaining a continued impression, the sensation it communicates being intermittent. Though thus inferior in vivacity and permanence, astronomers have observed the curious fact, that very small stars, invisible to direct, may be seen by indirect vision. "In this way," say Messrs Herschel and Louth, "a faint star in the neighbourhood of a large one will often become very conspicuous, so as to bear a certain illumination, which will yet totally disappear, as if suddenly blotted out, when the eye is turned full upon it, and so on, appearing and disappearing alternately as often as you please." The intermittent impression received by indirect vision appears to arise from the retina beyond the axis alternately becoming sensible and insensible to the rays of light falling upon it. If this be the reason, it is very remarkable how soon, after a little repose, it regains its sensibility. That it is so, however, appears from the circumstance, that when the experiment is continued for some time, the periods of insensibility are prolonged, and that at the moment when it begins to be insensible the retina is instantly restored to its susceptibility by a momentary closure of the eyelids.

In obscure light even direct vision becomes intermittent, as may be found by attempting to read small print or written characters by moonshine, or in twilight. If we fix an eye on objects we experience the necessity for a painful effort to enable us to distinguish them, and after all they appear and disappear, from the faint light with which they are illuminated not being sufficient to produce an image strong enough to effect a continuous impression on the retina.

Sir David Brewster justly remarks, "These affections are no doubt the source of many optical deceptions which have been ascribed to a supernatural origin. In a dark night, when objects are feebly illuminated, their disappearance and re-appearance must seem very extraordinary to a person whose fear or curiosity calls forth all his powers of observation." The impression of light upon the retina is not removed the instant the light is withdrawn, but remains for sometime impressed. It has been ascertained that the light of a live coal moving at the distance of 165 feet maintains its impression on the retina during the seventh part of a second. If, therefore, we whirl a burning stick round in a circle seven times in a minute or less, it will appear a continuous circle of fire. In the same way meteors, such as falling stars, form a line of light, and the electric spark darting across a dark thunder cloud, appears as a continuous flash of lightning. For the same reason, when our eyes are fixed on objects, as in reading, we never lose sight of them, notwithstanding every now and then the upper eyelid moves over the anterior surface of the eye, to diffuse over it the tears; but so quickly is this effected, that both the depression and elevation which constitute the twinkling of the eyelid are completed in at most the seventh part of a second, and consequently no interruption takes place.

In his interesting work on Natural Magic, Sir David Brewster states, " Another class of ocular deceptions have their origin in a property of the eye which has been very imperfectly examined. The fine nervous fabric which constitutes the retina, and which extends to the brain, has the singular property of being *phosphorescent by pressure*. When we press the eyeball outwards by applying the point of the finger between it and the nose, a circle of light will be seen, which Sir Isaac Newton describes as 'a circle of colours like those of a feather of a peacock's tail.' If the eye and the finger remain quiet, these colours vanish in a second of time; but if the finger be moved with a quivering motion, they appear again." After further statements Sir David Brewster continues—" We are led, therefore, to the important conclusions, that when the retina is compressed in total darkness, it gives out light; that when it is compressed when exposed to light, its sensibility to light is increased, and that when it is dilated under exposure to light, it becomes absolutely blind, or insensible to all luminous impressions.

" When the body is in a state of perfect health, this phosphorescence of the eye shews itself on many occasions. When the eye or the head receives a sudden blow, a bright flash of light shoots from the eyeball. In the act of sneezing, gleams of light are emitted from each eye, both during the inhalation of the air, and during its subsequent protrusion; and in blowing air violently through the nostrils, two particles of light appear above the axis of the eye, and in front of it, while other two luminous spots unite into one, and appear as it were about the point of the nose, when the eyes are directed to it." He again says—" In a state of indisposition the phosphorescence of the retina appears in new and more alarming forms. When the stomach is under a temporary derangement, accompanied with headache, the pressure of the blood-vessels on the retina shews itself in total darkness, by a faint blue light floating before the eye, varying in its shape, and passing away at one side. This blue light increases in intensity, becomes *green* and then *yellow*, and sometimes rises to *red*, all these colours being frequently seen at once, or the mass of light shades off into darkness. When we consider the variety of distinct forms which, in a state of perfect health, the imagination can conjure up when looking into a burning fire, or upon an irregularly shaded surface, it is easy to conceive how the masses of coloured light which float before the eye may be moulded by the same power into those fantastic and natural shapes which so often haunt the couch of the invalid, even when the mind retains its energy, and is conscious of the illusion under which it labours. In other cases, temporary blindness is produced by the pressure upon the optic nerve, or upon the retina, under the excitation of fever or delirium. When the physical cause which produces the spectral forms is at its height, there is superadded a powerful influence of the mind, which imparts a new character to the phantasms of the senses."

Now in all this Sir David Brewster considers light to be absolutely present, and that the eye is a source of light. A more correct view, however, is derived from the fact, that a nerve of specific sense like the optic, can convey to the mind no other impression, when irritated, than such as corresponds with its individual function. Thus the olfactory or auditory nerves can respectively, when irritated, from whatever cause the irritation arises, merely convey the impressions of smell or audition. So, likewise, with the retina and optic nerve: when excited in any way whatever, as from a blow, from pressure, or from being transfixed by the instrument of the surgeon, pain is not communicated by it, but an impression in accordance with the only sensation it is calculated to transmit, and a flash of light is, as it were, perceived of greater or less intensity according to the energy of the exciting cause.

Before adverting to other considerations with respect to the action of this admirable organ, it will be necessary, as far as our limits will permit, to direct our attention to some of the properties of light, that we may be better enabled to comprehend the exceeding beauty and excellent adaptation of the organization.

Refraction of Light.—When rays of light pass through the same medium, they keep in perfectly straight lines; but when they pass from one medium to another, they change their direction, that is, their straight course is broken or refracted. It is a general rule that rays passing from a dense into a rare medium incline from the perpendicular, as from water into air, and conversely when they pass from a rare to a dense medium, they are bent towards the perpendicular, as from air into water. This may be illustrated by taking an object such as a shilling, and fixing it at the bottom of an empty basin, then retiring backwards until the brim of the basin hides it; now let water be poured into the vessel, and the coin will again come into light. Thus, in Fig. 27, let *a* be the shilling at the bottom of the basin, and *c* the eye. While the vessel is empty, the eye cannot receive a ray nearer the coin than *d*, but when water is poured in, the light from the shilling proceeding through the water in the direction *a b*, when it reaches the surface and passes into the air, its direction is changed, and inclines from the perpendicular in the path *b c*. In this line it reaches the eye, and the coin becomes visible. When the rays of light fall perpendicularly on a surface, they suffer no refraction, but continue in the same direct line.

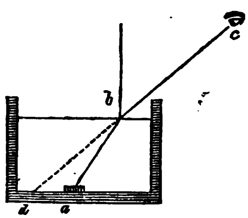

FIG. 27.

When the rays passing through such a medium as the air, fall upon a lens of greater refractive power than the air, they are refracted towards the perpendicular, or concentrated into a smaller cone; and the degree of concentration is in proportion to the convexity of the lens, so that a lens of greater convexity will effect a greater concentration than one whose convexity is less. Rays from a level surface, falling upon a sphere, reach it at different angles, in consequence of the different distances of the several radiating points from the several parts of the sphere on which they are directed, and therefore (if the refractive power of the sphere throughout be the same) some of the rays will undergo a greater refraction than others, according to their angle of incidence, and the focus of all will not be the same. This is termed spherical aberration.

Now, a ray of light, in passing from the air in order to reach the retina, has to traverse four transparent media of different densities, of different sphericities, and of different refractive powers, viz. the cornea, the aqueous humour, the crystalline lens, and the vitreous humour. According to Sir D. Brewster (*Natural Philosophy*), the following are the refractive powers of the humours of the eye:—

Aqueous Humour.	Crystalline Lens. Surface.	Crystalline Lens. Centre.	Crystalline Lens. Mean.	Vitreous. Humour.
1.336.	1.3767.	1.3990.	1.3839.	1.3394.

According to the same philosopher, the refractive power of atmospheric air is 1.000294, and of water 1.336.

If we take a double convex lens, such as a common magnifier, and hold it opposite a window in a room, and place a sheet of paper behind it, at a proper distance, we shall see depicted on the paper a perfect image of the window diminished according to the convexity of the glass. The greater the convexity, the image is so much the more diminished, and the closer must the glass be held to the paper; according to the distance also at which the window is placed will be the size of the image. We shall likewise perceive that the relative position of the parts of the window are exactly inverted, the upper sash being the lowest in the image, and the right side on the left. Moreover, we shall find that when the glass is so held as to make the central bars sharply defined, those at the margin appear obscure, and conversely when the side bars are brought out distinctly; these differences being occasioned by the different degrees of refraction that the rays suffer at the centre and margin of the lens, producing spherical aberration. Upon these properties of the lens depend the powers of optical instruments, such as the telescope and microscope, which have contributed so much to extend the sphere of human knowledge—the one bringing within our reach stars and clusters of stars placed at such vast distances that without its aid we must for ever have remained ignorant of them, and the other declaring to us objects so minute as altogether to elude the naked eye. The camera obscura in its most simple form is nothing more than a lens fixed in a hole of a window-shutter, and all light excluded from the room, excepting what is admitted through the lens.

On similar principles, though more complicated, yet with the most perfect adjustment, is the eye constructed. As in the camera obscura, the rays from the different objects within the sphere of vision are collected and concentrated, so as to be depicted on the retina in an image of the utmost accuracy. Those rays which in passing through the cornea and aqueous humour become subject to the greatest degree of refraction, fall on those parts of the lens which possess the least refractive power, and conversely, so that spherical aberration is thus obviated.

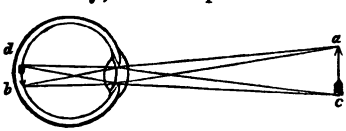

FIG. 28.

The image on the retina is reversed from above to below, and from right to left. In Fig 28, the rays from the arrow *a c* proceed in the directions *a b* and *c d*, and produce on the retina the inverted image *b d*. That this occurs in the eye may easily be seen by procuring the fresh eye of a bullock, and shaving off with a sharp knife the back part of the sclerotic coat till it becomes translucent, when an inverted image will be seen on the retina; or a small portion of the coats of the eye may be removed entirely in the axis of vision, and the space covered with a piece of transparent oiled silk, which will afford for a short time a most perfect, though minute, camera obscura.

A great many theories have been started in order to account for our being able to see objects in their proper position, although their image must be inverted upon the retina. All these theories attempt to explain the fact on physical principles, which have perhaps little or nothing to do with the matter. It is not the retina which perceives or sees, but the mind. The eye is merely the instrument, and, without the mind to use it, would be as inoperative and useless as the microscope is to an irrational creature.

To examine the comparative merits of the different opinions which have been entertained appears superfluous, although many of them proceed from interesting facts connected with the organs of sight, and tend to elucidate the perfection of the mechanism. With respect to the action of mind on matter, and matter on mind, there exists a barrier which man in his present state seems never to be destined to pass, and even the very attempt to do so appears worse than useless.

There are two states of the eye depending on the condition of its refractive apparatus, that the laws of refraction satisfactorily explain. In the one, the refractive power is too great, producing short-sightedness; in the other it is deficient, causing long-sightedness.

Short-sightedness arises from the rays of light being brought to a focus before they reach the retina, and consequently producing an indistinct picture on the retina, as seen in Fig. 29. Those who labour under this defect require to bring an object close to the eye, in order to see it distinctly.

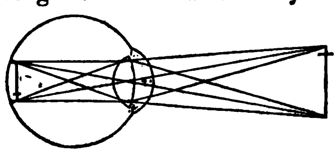

Fig. 29.

They also corrugate the eyebrows, and diminish the aperture between the eyelids, so as to exclude as much as possible the more oblique rays. Short-sightedness occurs most frequently in early life, and may even be acquired by habit. Some employments tend to induce it, as the art of the engraver, and that of the watchmaker. Wearing convex glasses is capable of producing it. As it formed an adequate ground for exemption for persons who fell in the conscription list under Napoleon, young lads took to the constant wearing of very convex glasses, for the purpose of artificially inducing it —a practice by which they not unfrequently succeeded in their object. The inconveniences arising from short-sightedness are obviated by using doubly concave glasses, thereby producing that degree of divergence in the rays coming from distant objects which compensates for the too great refractive power of the eye.

This defect of the eye may arise from several causes: from too great a convexity either of the cornea or of the lens—from too great density of the humours, especially the crystalline—and from the space between the lens and the retina being too short. Where it depends on too much convexity, as age approaches it may disappear; but where too great density is the cause, age is apt rather to aggravate than relieve it. For while in the young the convexity both of the cornea and the lens is greater than in advanced life, the less density of the humours counterbalances it: and again, as life advances, the more scanty supply of humours, along with the diminishing convexity, are neutralized by the increasing density; therefore, if these keep pace with each other, the eye remains till a very protracted period of life without the necessity for artificial assistance.

Long-sightedness depends on the opposite causes which produce the former condition, in consequence of which the rays are not brought to a focus sufficiently soon, and the image would fall beyond the retina, as in Fig. 30. It

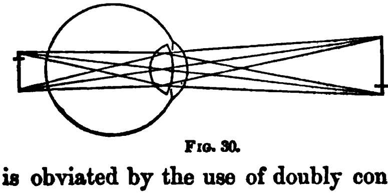

Fig. 30.

is obviated by the use of doubly convex glasses, adapted to the extent of the deficiency. It generally appears about middle age, and first displays itself by a difficulty in making out small print, or of following the next line in the order of succession, especially in candle light. A person labouring under this defect looks as if beholding objects at a distance, elevates the eyebrows, and opens widely the eyelids. To effect this change, where it depends on an alteration of the lens, it sometimes requires several months before the change is uniformly completed. Sir D. Brewster very justly observes, "If the human eye is not managed with peculiar care at this period, the change in the condition of the lens often runs into cataract, or terminates in a derangement of fibres, which, though not indicated by opacity, occasions imperfections of vision that are often mistaken for amaurosis and other diseases. A skilful oculist, who thoroughly understands the structure of the eye, and all its optical functions, would have no difficulty, by nice experiments, in detecting the very portion of the lens where this change has taken place—in determining the nature and the magnitude of the change which is going on—in applying the proper remedies for stopping its progress—and in ascertaining whether it has advanced to such a state that aid can be obtained from convex or concave lenses. In such cases lenses are often resorted to before the crystalline lens has suffered an uniform change of figure or of density, and the use of them cannot fail to aggravate the very evils which they are intended to remedy. In diseases of the lens, where the separation of fibres is confined to small spots, and is yet of such magnitude as to give separate coloured images of a luminous object, or irregular halos of light, it is often necessary to limit the aperture of the spectacles, so as to allow the vision to be performed by the good part of the crystalline lens."

In the above remarks on refraction, light has been regarded as a simple substance, and at first scarcely anything, one should suppose, could be more simple in its constitution than the light of the sunbeam. This, however, is not the case, for it has been satisfactorily shewn that the pure white light of the sun is in reality composed of rays possessed of different colours, each of which differs in its refrangibility.

To the illustrious Sir Isaac Newton we are indebted for the discovery of the compound nature of light. This he effected in the following manner: In a darkened room, having admitted through a small hole, H, in the window-shutter, E F, a beam of sun light, S, he interposed a glass prism, A B C, as in Fig. 31, through which the light was

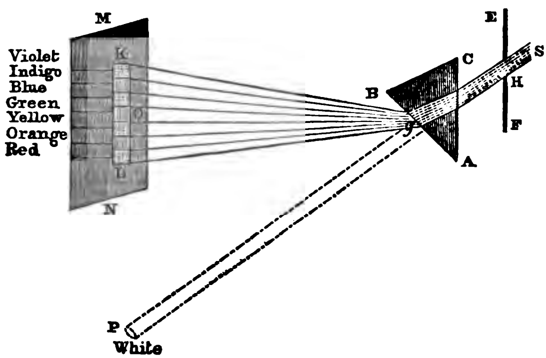

FIG. 31.

transmitted, when, instead of continuing in the straight dotted line, S P, as white light, in passing through the prism its direction was changed at *g*, and received on the screen M N, producing the spectrum K O L, composed of seven different colours, namely, *red*, *orange*, *yellow*, *green*, *blue*, *indigo*, *and violet*. The red, it will be seen by examination of the figure, is that which deviates least from the original direction of the sunbeam, or it is the least refrangible, while the violet is situated at the opposite extremity, having been subjected to the greatest degree of refraction, the others being intermediate in various degrees. The image received on the screen is termed the *solar* or *prismatic spectrum*, and the tints the *prismatic* or *primary* colours, and their mixtures or combinations *secondary*.

Light is likewise decomposed by transmission through coloured media, during which some of the colours are retained or absorbed, and others transmitted. When white light is transmitted through blue glass, for example, the glass absorbs the other colours, and transmits the blue, and the recombination of the absorbed and transmitted light would again form white light; they are therefore complements of each other, and hence called complementary. As they harmonize with one another in painting, and produce a pleasing effect in relation to each other, they are likewise termed harmonic. When a substance absorbs all the rays, black is produced, and when it reflects or transmits the whole, white light retains its integrity.

The different colours occupy different spaces on the spectrum. They are not bounded by well defined lines, but slide gradually into each other. From the most accurate estimates Sir Isaac Newton could form of the extent of the respective spaces they occupy, he arrived at the following results: Supposing the colours are arranged in a circle, as in Fig. 32, of the 360 degrees into which the circle may be divided, red will occupy 45, orange 27, yellow 48, green 60, blue 60, indigo 40, and violet, 80.

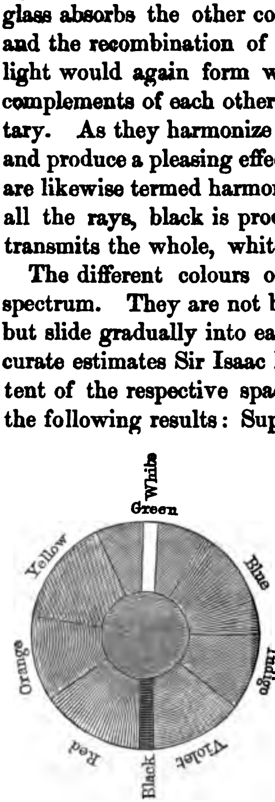

Fig. 32.

The composition of light may be proved by synthesis or combination, as well as by analysis or decomposition. If we paint upon a circular board, Fig. 32, the different colours, as seen in the spectrum, then, if the board be whirled quickly round on its centre, the colours will be blended together so as to appear nearly white; and if the paints were of sufficient purity and lustre, they would appear perfectly white.

When the eye has been for some time strongly impressed with any particular colour, and then directed to a sheet of white paper, the paper does not appear white, nor of the colour impressed, but of a different colour, varying according to that which had been impressed. Thus, if we place a red wafer on a sheet of white paper, and keep one eye for some time steadily fixed on a mark in its centre, after some time, if the wafer be struck off, and the eye kept fixed on the space it occupied, an image of the same form as the wafer will remain, but of a bluish green, or the same image will appear by moving the eye from the wafer, after it has become sufficiently impressed, to some other part of the white paper. The colour which replaces that of the wafer is termed the *accidental*, and is identical with the *complementary*. In making the experiment, if the wafer is white, and placed on a dark ground, the accidental colour will be black, or if black on a white ground, and the wafer removed, the spot it occupied appears whiter than the rest. The accidental colour is likewise called opposite, because, when the prismatic spectrum is arranged in a circle, as in Fig. 32, the primary and accidental colours are directly opposite to each other, as in the following table:—

Colour of Wafer.	Accidental Colour, or of the Spectrum.
Red	Bluish Green.
Orange	Blue.
Yellow	Indigo.
Green	Violet Reddish.
Blue	Orange Red.
Indigo	Orange Yellow.
Violet	Yellow Green.
Black	White.
White	Black.

The explanation which accidental colours admit of is sufficiently simple: When the eye has, for example, been for a sufficient time impressed with the rays from the red wafer, the spot on the retina upon which they fall becomes insensible to red light, and therefore, when the eye is turned upon the white paper, the red rays of the white light make no impression, being as it were blotted out or withdrawn, leaving the other rays which make up the complementary colour, or bluish green. And in the case where a black wafer is placed on a white ground, a corresponding spot on the retina is protected from the white light to which the surrounding parts of the nervous web are exposed; its sensibility is therefore increased, and when the black wafer, acting as it were like a screen, is withdrawn, its greater sensibility is displayed, and a spot whiter than the rest of the field, of the same form as the wafer, appears. Again, where a white wafer is used on a black ground, on turning the eye on a sheet of white paper, a black spectrum appears, partly from the increased sensibility of the greater portion of the retina, and the diminished sensibility of the part impressed with the white light.

When white light undergoes refraction, it at the same time suffers decomposition. In optical instruments of great power, this produces confusion and indistinctness in the image, an imperfection obviated by an ingenious combination of substances possessed of different degrees of refractive power, so that the combined result is a colourless spectrum. Instruments constructed on these principles are termed acromatic.

Although the different refractive powers of the humours of the eye, and especially the different density of the lens at its centre and circumference compensate for spherical aberration, it does not appear to be constructed so as to act as an acromatic instrument, for if a card be so placed before the eye as to exclude the light from entering the pupil, excepting at a small segment at its margin, a prismatic spectrum will be distinctly visible, which would not have happened had it possessed the power of acromatic adjustment. But such power has been shewn to be unnecessary, for by calculation it appears that the deviation of the different coloured rays in the eye is too small to produce indistinctness of vision.

Many curious instances have been recorded in which individuals were totally insensible to certain prismatic colours, although, in other respects, their eyes were capable of performing in a perfect manner the other functions of vision. Some could only appreciate blue and yellow. One was incapable of distinguishing the ripe Siberian crab-apple, and another ripe cherries, from the leaves, except by form and size. In one instance, a naval officer purchased a blue uniform coat and waistcoat, with red breeches to match the blue; in another, a tailor patched the elbow of a blue coat with a piece of crimson cloth, considering them a proper match; and in several such instances the defect has been found to run in families.

Estimation of Magnitude and Distance.—When treating of the motions of the eye, we shewed, that in order to have single vision with two eyes, it is necessary that both the eyes should converge to a greater or less extent, according to the distance, so that the rays of light coming from the same points of an object may fall on the point of distinct vision in the centre of the retina of both. To effect this, a voluntary muscular effort is required to produce the requisite degree of convergence of the axes of the two eyes, a great degree being necessary for objects placed close to the eye, and a small degree for those at a distance. In consequence of this voluntary effort, an idea is obtained of the relative situation and distance of objects.

Besides convergence of the axes, we are able to ascertain the size and distance of an object by other means, such as the visual angle, the intensity of light, shade, and colour, and by contrasting it with known objects.

The visual angle is that formed by the rays proceeding from the extremities of an object, and crossing the lens previous to being depicted on the retina, so that the visual angle subtended by the object *a b*, Fig. 33, is equal to that subtended by its image *e d* on the retina. It is evident that if all objects were at equal distances from the eye, and of the same magnitude, they would subtend on

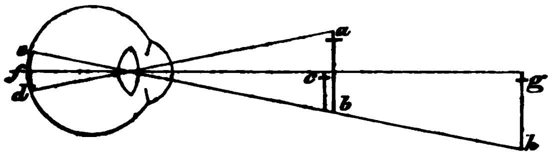

FIG. 33.

the retina at the same visual angle, and if not of the same magnitude, the difference would be accurately indicated by the difference of the angle subtended by them; thus the comparative size of the two crosses *a b* and *c b*, is represented by their images on the retina, *e d* and *e f*. But the cross *g h*, which is twice the size of *c b*, subtends at the same visual angle, and is represented on the retina of the same size as *e f*. We thus perceive that the visual angle does not give us a correct idea of the relative magnitudes of bodies, unless at the same time we are acquainted with their respective distances from the eye; and conversely, we cannot judge accurately of their distances without being aware of their magnitudes. A man on horseback, when near, is subtended at a certain visual angle, which lessens with the increase of the distance, yet we find no difficulty in accurately estimating the size from our knowledge by previous experience; but when objects are at a great distance, when we have not the means of comparing them with nearer objects, we are constantly liable to fallacy, believing them to be much smaller than they really are, as is the case for example with the heavenly bodies. Thus, a sixpenny piece, held at some distance from the eye, will shut out the sun, whose diameter is 888,000 miles. The sun and moon, subtending at nearly the same visual angle, appear to us of the same size, although we are aware of the mathematical accuracy with which it has been determined that the former is distant 96,000,000 of miles, and the latter only 240,000. For the same reason, when looking along a street or along an avenue of trees, the houses or trees that are nearest to us on the foreground appear largest, and the rest gradually diminish, according to the distance, so that if we could imagine a line drawn along the tops and bottoms of the objects, they would appear to meet at a point, as in Fig. 34.

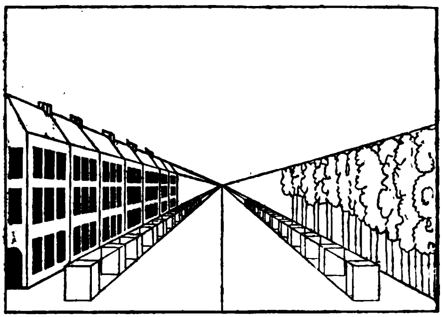

FIG. 34.

Objects of every figure, excepting that of a sphere, vary in form according to the aspect in which they are presented to the eye. When an oval body, for example, is situated so as to present one of its ends, its smallest diameter only is seen, and it appears spherical; but when so placed as to present a greater diameter, the image is oval or elliptical. If we take a rod, and hold it obliquely, its length will appear more or less shortened according to the angle at which it is held; for the same reason the slope of a rising ground would appear much greater if placed perpendicularly. The appearance arising from the obliquity of position of an object is termed *foreshortening;* and the art which treats of the apparent size of an object, according to the distance, and of foreshortening according to position, is termed *perspective*—an art of the utmost importance in painting. The intensity of light and shade in which an object is seen diminishes according to the square of the distance, being only one-fourth as powerful at twice the distance, one-sixteenth at four times, and so on, as indicated by the squares seen in the front of the houses and trees seen in Fig. 34. By this law, we are enabled to judge of the distance of bodies with considerable accuracy. Notwithstanding, numerous optical illusions spring from this source. Thus, distant hills appear nearer in bright sunshine than in a cloudy day, their outlines being more sharply defined. The sky appears less distant directly over the head than nearer the horizon, because the rays of light have to pass through a less quantity of atmosphere, and for the same reason partly the sun and moon appear larger in rising and setting than when high in the zenith.

When we look at the revolving light of a light-house it appears to approach as the intensity of the light increases, and again to recede as it becomes dim. In the same way a lamp in the street brighter than the rest appears nearer. The old city of Edinburgh, viewed from Prince's Street, in a dark evening, when the windows and lamps are lighted up, presents a very remarkable example of optical illusion, which even those long familiar with the scene cannot altogether divest themselves of, and never fails to make on the mind of a stranger a strong impression of romantic grandeur. The tall houses rise one above another on the high precipitous ridge, of every form and architecture used for these last two hundred years, with windows of every variety of shape and size; those belonging to the more wealthy shops of the High Street, being better lighted, appear nearer than the more humble establishments at the base of the precipice, that are closer to the spectator. The illusion is so complete that it is impossible, as far as seeing can inform us, to believe otherwise than that we are looking on a range of fantastic buildings between thirty and forty storeys in height.

The shade afforded by objects is in proportion to the intensity of light. The shadow of the body in sunshine is more strongly defined than by moonlight. In like manner, it becomes less intense according to the distance, until at length the shadows are so blended together that the range of mountain and plain presents one uniform undefined outline.

Without the alternation of light and shade, the only means of distinguishing bodies would be by the difference of colour. Unless from the prominences and depressions brought out by light and shade, the landscape would present one uniform unvaried aspect. The principles, therefore, which regulate light and shade are of the greatest importance to the painter. By proper attention to them, and a judicious combination with the laws of perspective, he is enabled to produce the most perfect optical illusion, representing, on a flat surface of canvas, an extensive scene of mountain and plain, of woodland and lake, near and distant objects, according to the impression he desires to convey; the outline of objects on the foreground being bold and sharply defined, while they are made gradually to fade away in the distance.

The relative proportion which unknown objects bear to those whose magnitude we are aware of from previous experience, enable us to judge of their size and distance. It is for want of subjects wherewith to institute comparisons that difficulty is experienced in estimating the extent of an unvaried plain, or the exact distance of objects at sea,—a difficulty which every landsman especially experiences at sea when he endeavours to estimate the distance of vessels, or that of the shore; and consequently he commits the greatest errors, according to the height of the land, the degree of atmospheric clearness, and so forth. Partly from the same cause the sun and moon appear larger when nearer the earth. The intervention of known objects, such as a tower, a city, or a mountain, cause these heavenly bodies to appear much larger. Arnott observes, " The sun and moon, in appearance from the earth, are nearly of the same size, viz. always occupying in the field of view about the half of a degree, or as much as is occupied by a circle of a foot in diameter, when held about 250 feet from the eye, which circle, therefore, at that distance, would just hide either of them. Now, when a man sees the rising moon apparently filling up the end of a street, which he knows to be a hundred feet wide, he very naturally believes that she then subtends a greater angle than usual, until the reflection occur to him, which it rarely will of itself, that he is using, as a measure of her size, a street known indeed to be a hundred feet wide, but of which the part concerned, owing to the distance, appears to his eye exceedingly small. The width of the street near him may occupy sixty degrees in his field of view, and he might see from between the houses many broad constellations instead of the moon only; but the width of the street far off may not occupy, in the same field of view, the twentieth part of a degree; and the moon, which always occupies half a degree, will then appear comparatively large. The kind of illusion now spoken of is still more remarkable when the moon is seen rising near still larger known objects, for instance, beyond a town, or a hill, which then appear within her luminous circle."

Tall steeples appear much taller than they really are, from being viewed without any object to compare them with, and this effect is much increased by their being surmounted by a cross or other object, which again, for the same reason, appears much smaller than it actually is, and thus tends still further to magnify the apparent height of the steeple. The cross at the top of the dome of St. Paul's is thirty feet from the ball to the summit, yet, when viewed from the street, it does not appear to be more than one-sixth of that height; on this account, too, statues placed on tall pillars require to be of colossal size. In fact, the effect produced by architectural structures, like painting, in a great measure depends on optical illusion. From the principles of foreshortening likewise, objects seen from great heights, especially from high precipices, appear much diminished. This effect is very strikingly displayed in the Shetland island of Foula, the celebrated Thule of the ancients, the favourite resort of innumerable flocks of sea birds. Here there is a precipice 1100 or 1200 feet perpendicular, affording to those who have nerve enough to contemplate the scene beneath, a spectacle more stupendous than the wildest fancy could imagine. From this giddy height, the thousands of birds beneath skimming through the air in varied circles, each according to its kind, seem like so many moths and butterflies, and the green expanse of water beyond, with the heaving and curling waves, appears like another sky studded with fleecy clouds.

Habit tends in some measure to dissipate these optical illusions, and persons who are accustomed to view objects from different heights, and to compare them with neighbouring and interposed known objects, are enabled readily to allow for the effects of foreshortening, and obtain correct notions respecting their magnitude and distance. The tall houses and high precipices of Edinburgh and its vicinity, are well fitted for imparting to its inhabitants this kind of knowledge. Still, when a new object is presented to the view, of unusual grandeur and magnitude, previous education fails in enabling the mind to obtain a just conception. On this account, it is not till after some time, and repeated observation and reflection, that the stupendous magnificence of such structures as St. Paul's is justly appreciated. I myself had a very forcible instance of this on visiting St. Paul's last year for the first time. On a very favourable day in August I ascended to the ball, and spent some hours in contemplating the city from the lantern and outer galleries of the dome. I did not, in the slightest degree, observe any diminution of the persons and other objects passing on the streets, which so frequently strikes strangers from the same situation. This I attributed to my being in the habit of seeing objects from similar heights in and around Edinburgh, as from the Castle, the Calton Hill, and Salisbury Crags, and therefore accustomed to estimate and allow for the influence of relative situation.

Upon descending, however, to the whispering gallery, and looking over upon the people walking on the marble floor beneath, I was not a little surprised to notice that their persons were reduced to the most dwarfish dimensions. The choir also appeared very much smaller than my recollection and judgment knew it to be, and by no effort on my part could I dissipate the illusion. Inquiring of the attendant if the persons beneath appeared to him diminished, he assured me they did not.

Now this illusion on my part, and not on his, depended upon the conceptions which at the time we respectively entertained of the true relative size of that splendid structure, my untutored mind was incapable of grasping at once its grandeur and real magnitude, and consequently a reduced standard was employed when endeavouring to comprehend it; and by the same reduced standard, the persons on the floor were examined, and therefore they seemed dwarfish, while custom had habituated the eye, or rather the mind of the attendant, to the estimation of their just relative proportion.

The painter has recourse to contrast with the greatest advantage. In order to convey an idea of the size and distance of unknown objects, he brings upon the field known objects to serve as a standard of comparison. Contrast therefore is one of the most efficient means by which we judge of size and distance.

CHAPTER IX.

HEARING.

Of the Nature of Sound—Grave and Acute Tones—Number of Vibrations appreciable by the Human Ear—Transmission of Sounds—Velocity of Sound—Stethoscope—Echo—External Ear adapted for collecting Vibrations—Middle Ear or Drum constructed for the Transmission and Modification of the Vibrations—Different Apparatus of—Internal Ear or Labyrinth the immediate seat of the Sense of Hearing—Construction and Apparatus of—General Inferences deduced from the Examination of the Structure as a whole.

Sound has no existence as a distinct substance, but is merely the result of certain conditions of bodies. When a body is struck, its particles are thrown into a state of motion which extends in every direction to a greater or less distance, according to the intensity of the impulse. Thus, if a pebble be cast upon the smooth and tranquil surface of a pool of water, undulating circles are produced; these radiate from the point struck in every direction of the surface, gradually diminishing, till they imperceptibly subside altogether in the distance. The undulations or oscillations in this instance are not confined to the surface of the water, where they are visible, but extend to the whole body of water, in every direction, and likewise to the air in contact with it; consequently the point where the water and pebble come in collision is the centre of a sphere from which the oscillations are communicated to a hemisphere of water in one direction, and to a hemisphere of air in the other. We may take another example: If an elastic wire be fixed at one end, and the other laid hold of and pulled to one side, when set free, it will move towards the point from whence it was withdrawn, where, however, it will not stop, but proceed beyond it, and again return to the point where it was let go, and thus it will continue to traverse the space, till at last it comes to rest. During these movements it will communicate to the air in contact with it similar vibrations. These motions are similar to the oscillations of a pendulum. They may be performed with such rapidity that the eye cannot follow them, while in the measured movements of the pendulum they are easily noted.

When the vibrations are slow or few in a given time, the individual impulses may be counted; but when the motions are performed with rapidity, their individuality is lost, and a continnous sound or tone is produced. When the vibrations of a sonorous body are numerous in a given time, or follow each other in quick succession, the sound is acute or high; and when fewer during the same period, a grave or low sound is produced. The highest tones appreciable by the human ear consist of 32,000 vibrations in a second, and the lowest 32.

On this point Dr Wollaston observes, (*Phil. Trans.* 1820), "In the natural healthy state of the human ear, there does not seem to be any strict limit to our power of discerning low sounds. In listening to those pulsatory vibrations of air of which sound consists, if they become less and less frequent, we may doubt at what point tones suited to produce any musical effect terminate; yet all persons but those whose organs are palpably defective continue sensible of vibratory motion, until it becomes a mere tremor, which may be felt and even almost counted.

"On the contrary, if we turn our attention to the opposite extremity of the scale of audible sounds, and with a series of pipes exceeding each other in sharpness, if we examine the effects of them successively upon the ears of any considerable number of persons, we shall find (even within the range of those tones which are produced for their musical effects) a very distinct and striking difference between the powers of different individuals, whose organs of hearing are in other respects perfect, and shall have reason to infer that human hearing in general is more confined than has been supposed with regard to its perception of very acute sounds, and has, probably in every instance, some definite limit, at no great distance beyond the sounds ordinarily heard."

He states further, "The suddenness of transition from perfect hearing to total want of perception, occasions a degree of surprise, which renders an experiment on this subject, with a series of small pipes, among several persons, rather amusing. It is curious to observe the change of feeling manifested by various individuals of the party in succession, as the sounds approach and pass the limits of their hearing. Those who enjoy a temporary triumph, are often compelled, in their turn, to acknowledge to how short a distance their little superiority extends."

Dr Wollaston mentions, that a friend of his could imperfectly hear a note four octaves above the middle E of the pianoforte, and that he could not hear the F next above it, although his hearing in other respects was perfect, and his perception of musical pitch as correct as that of any other person. He likewise gives instances where the chirp of the grasshopper could not be heard; and he observes, that "inability to hear the piercing squeak of the bat seems not very rare, as I have met with several instances of persons not aware of such a sound." He also cites the case of a gentleman who could never hear the chirping of a house sparrow.

The number of vibrations which a string of a musical instrument makes in a given time varies according to its *length*, *tension*, and *thickness*, consequently, according as these conditions vary, so will the tones produced. If a string vibrates a hundred times in a second, when shortened by one-half its length it will vibrate two hundred times, and give out a sound more acute, or higher, by one octave, and so on according to its length. If a string stretched or rendered tense with a force equal to one pound gives out a hundred vibrations, with a tension of four pounds it will vibrate two hundred times, with nine pounds three hundred times, with sixteen pounds four hundred times, and so on, the number of the vibrations being in proportion to the square roots of the forces with which the string is stretched. A string reduced to one-half its thickness, with the same length and tension, will vibrate twice as fast, to one-third three times as fast, and so on according to the quantity of matter put in motion. These principles are fully illustrated by a stringed instrument such as the violin or harp.

The extent of the vibrations, or the distance the elastic body deviates from the point of rest, depends upon the force applied. If the force with which it is struck be small, the sound elicited will be weak, and will soon cease; but when a great force is used, the oscillations are correspondently great, and a loud sound is produced, which will be heard from afar, and continue for a great length of time.

Sound is transmitted or conducted by different bodies with different degrees of velocity. In air it travels at the rate of 1142 feet in a second; in sulphurous acid gas it moves only at the rate of 751 feet; while in hydrogen it passes at the velocity of 3000 feet in a second. Through liquids its velocity is greater, moving in water at the rate of 4708 feet in a second, and in solids it is greatly augmented, passing through tin at the rate of 8175 feet, and through iron, glass, and some kinds of wood, at the rate of 18,530 feet in a second.

By these facts we are enabled to understand how, when a gun is fired at a distance over the smooth expanse of a frozen lake, two reports are heard after the flash,—first a sharp and loud one, transmitted by the solid ice, and then a weaker and duller sound through the air. In proportion to the conducting power of bodies, is the force and distance to which sounds are transmitted; accordingly fluids transmit sounds further, and with greater force than aëriform bodies, and solids again very much surpass fluids in these respects. A blow struck by the hammer of the workman in the diving bell is distinctly heard several fathoms above, and if the head be plunged into the water, each stroke is heard with painful intensity. The scratch of a pin at one end of a long log of wood is distinctly heard by the ear applied to the other, although it is quite inaudible through the air. The report of a cannon is heard to a much greater distance over the frozen surface of snow; under such circumstances, the firing has been heard at distances varying from one hundred to two hundred miles. Approaching footsteps are distinctly heard when the ear is applied to the surface of the ground, long before they become audible through the air,—a fact of which savages avail themselves in listening to the footsteps of their enemy or their prey. In like manner, by placing one end of a walking-stick to the ground, and the other upon the ear, hearing is facilitated; and if one end of a poker be placed on the ear, and be slightly struck, strong and clear sounds are perceived,—an experiment occasionally had recourse to in order to ascertain whether water in a kettle boils. For these reasons watchmen now strike the pavement to communicate with each other, which they are thus able to do to a greater distance than by the use of their old instrument, the rattle. A musical box, when held on the hand, may give out scarcely audible sounds, but when it is pressed upon the table, and more especially when placed on a sounding-board, its sounds become clear, and distinctly audible to a considerable distance.

An instrument known by the name of stethoscope is of the utmost practical importance to the physician, especially for investigating the nature and extent of diseases of the chest, whereby he is enabled with great precision to ascertain the character and seat of affections of the heart and lungs, from the sounds which they give out, and to regulate his practice accordingly.

Organized as we are for existence in an ocean of atmospheric air, we are much more familiar with, and better able to appreciate vibrations communicated through the air than other media, and circumstances which modify atmospheric sounds are not only detected with greater facility, but are likewise more interesting and important. The numerous changes to which the atmosphere is subjected from variations in temperature, quantity of moisture, and motion, very materially affect the transmission of sound through it. During the night, when the air is still, and of uniform density and temperature, sounds are heard to a great distance; but when the atmosphere is loaded with vapours, or in a fall of snow or rain, and also when it is composed of strata differing from each other in conducting power, the sounds are more limited, and rendered confused and indistinct. The indistinctness arising from the transmission of sound by media of different densities requires attention in the use of the stethoscope. Where the object is to investigate the sounds produced by the air in breathing, a hollow tube is the best adapted, as the ear receives the sounds by the same medium as that in which they are produced. On the other hand, when listening to the sounds produced by the motions of the heart, a solid cylinder is to be preferred, as being more in accordance with the nature of the organs which are the source of the sound. The intensity of sounds, and the distances to which they are conveyed, depend on the state of the air as to density. In a dry cold atmosphere, at the level of the sea, they are transmitted to vast distances with great sharpness and clearness, while at the top of a high mountain, such as Mont Blanc, the report of a pistol is not louder than that of an Indian cracker. The velocity of sound, and the extent to which it is conveyed, are affected by the wind, so that striking effects are produced when it either retards or conveys the distant report of artillery.

Sound, like light, is subject to reflection, and in this respect obeys similar laws, the angle of reflection being equal to the angle of incidence. When a stone is cast into a tranquil pool of water, the undulations which are produced on meeting with an impediment, such as the bank, or any other object, rebound, and the obstacle becomes the centre from which new waves proceed with an intensity diminished in proportion to the distance from the original centre. The reflected sound is termed an *echo;* and on meeting with a second impediment, it may again be reflected, so as to give rise to a second echo, and so on, according to the number of reflections, each becoming weaker than its predecessor, till they die away altogether. The rolling of thunder depends partly upon the sound being reflected from cloud to cloud, and through strata of air of different densities, though it also arises from the discharge of electricity taking place through a volume of air, perhaps miles in extent; consequently the sound from the point nearest the hearer first reaches his ear, while several seconds elapse before the arrival of the more distant, hence giving origin to a prolonged peal. As the passage of light for all distances on the surface of the earth may be considered as instantaneous, and as sound travels at the rate of about a mile in four seconds, the pulse at the wrist, in a healthy person, may conveniently serve for measuring the time between the lightning and the thunder, each beat of the pulse being taken as marking a second; the number of beats between the flash and report will enable us pretty accurately to estimate the distance of the electric shock.

Sound, like light, decreases in intensity in the inverse square of the distance, so that at double the distance it is only one-fourth part as strong, and so on; but when sound is transmitted along a tube, so as to prevent its spreading, the diminution is much less. In houses and manufactories, pipes are frequently fitted up for communicating verbal orders to distant apartments, attention being attracted by ringing a bell. Sounds are likewise to a certain extent prevented from spreading along the smooth surface of a lake, or along a level wall, and therefore conversation may be kept up at greater distances in such situations.

The reflections of sounds may be collected into a focus, so as to increase their intensity, and aid the organ of hearing in appreciating them. Dr Arnott mentions a remarkable instance of this concentration, where the sail of a ship rendered concave by a gentle breeze caused the sound to become audible at a great distance. He says, " It happened once on board a ship sailing along the coast of Brazil, a hundred miles from land, that the persons walking on deck, when passing a particular spot, always heard very distinctly the sound of bells, varying as in human rejoicings. All on board came to listen, and were convinced, but the phenomenon was mysterious and inexplicable. Months afterwards it was ascertained, that at the time of observation the bells of the city of St Salvador, on the Brazilian coast, had been ringing on the occasion of a festival. Their sound, therefore, favoured by a gentle wind, had travelled over a hundred miles of smooth water, and had been brought to a focus by the sail in the particular situation on the deck where it was listened to. It appears from this that a machine might be constructed having the same relation to sound that a telescope has to sight."

Upon the law of reflection of sound the instruments for assisting the sense of hearing are constructed. The *ear-trumpet*, with its wide mouth, collects the vibrations, and these being reflected several times as they pass along the curvatures, are finally collected to a focus at the smaller extremity, inserted into the passage of the ear, thereby enabling a person whose hearing has been blunted, to enjoy the exercise of this sense much better than he could otherwise do. The *speaking-trumpet* acts by reflecting the voice upon a particular point. To employ it efficiently, it is necessary that the words should be distinctly articulated, otherwise a confused noise only is communicated. By means of this instrument the commander at sea is enabled to transmit his orders aloft during the hurricane, in the midst of the noise and uproar of the wind and waves, or hail another vessel at a distance.

The Ear.—The organ of hearing may conveniently be divided into three portions:—*first*, the *external ear*, or auricle, by which the vibrations are collected, concentrated, and transmitted; *second*, the *middle ear* or *drum*, by which they are conveyed and modified in their intensity; and, *third*, the *internal ear* or *labyrinth*, wherein is lodged the auditory nerve for the reception of the vibrations, and by means of which the impressions are communicated to the brain, the seat of perception, where cognizance is taken of them, forming the ultimate limit of physical investigation.

The Auricle.—The general conformation and shape of the external ear must be sufficiently known to every one. In man it consists of the pavilion and the lobe; the latter, forming an appendage to the former, especially characterises this organ in the human subject. The pavilion consists of a cartilage, formed into several eminences and depressions, so arranged as to collect and concentrate the vibrations of the air at the orifice of the auditory passage, the elasticity of the cartilage well fitting it for this office. The cartilage is covered with a layer of very dense ligamentous fibre, which again is embraced with a covering of thin integument. In this part no fat is deposited, excepting a small quantity in minute cells of the lobe, and along the margin of the brim of the pavilion, as that substance would have tended to deaden the vibrations. The auricle is attached to the surrounding parts by ligamentous bands and by muscles. One of the muscles is composed of fibres proceeding from the pavilion upwards and forwards, to be connected with the layer which moves the hairy scalp; by its action the auricle is carried upwards and forwards. Another muscle arising from the skull behind the ear, is generally divided into distinct slips, which carry it backwards and downwards. Besides these there are several distinct slips of muscular fibres belonging to different portions of the pavilion, by which the tension of the different parts is regulated in accordance with the tone and intensity of the vibrations. In civilized life, where the comfort and safety of the individual is not so dependent on the acuteness of the external senses as they frequently are in the savage state, their powers are not exercised, and consequently not so perfectly developed as in the latter condition. Among savages, motion in the auricle is not unfrequently possessed to a considerable extent; while among those who are not so dependent upon the perfection of their external senses, perceptible movements are comparatively rare.

The external ear, strictly speaking, is confined to animals of the class mammalia, nor is it universal among them. The mole, the water shrew, and other diving animals, seals, and whales, are destitute of it. With respect to the mole, while burrowing through the soil, the vibrations will be transmitted to its organ of hearing with great intensity through the solid medium; and diving animals require an organization which may be adapted to the difference of intensity in the vibrations in water and in air, a difference that amounts to more than four to one: in the same way as they have to adapt their eye for seeing in the two media, so likewise is it necessary to adapt the ear for hearing, though it would appear that their sensibility to sonorous vibrations through air is by no means acute, so that opportunities are afforded to the whaler to approach unawares his huge but timid prey, and plunge his harpoon into its carcass. In like manner the seal and the walrus remain unconscious of the footsteps of their foe, till it is too late for retreat. Among land animals of this class, great diversities exist in the development of the auricle; in timid creatures, such as the hare and the rabbit, it is large, formed of several distinct pieces, moulded into various shapes, and endowed with great mobility, so as to be placed in the direction from whence the sound proceeds, and thus become capable of extensive adaptation to various intensities and velocities.

In birds, the arrangement of the feathers encircling the ear is in some degree calculated to fulfil the purposes of the auricle; and besides this, in owls several folds of integument, although destitute of cartilage, are evidently constructed with this intention.

The sonorous oscillations being collected and concentrated by the auricle, are conveyed along the auditory passage. This tube is about ten or eleven lines in depth, forming a cul de sac; its direction is somewhat winding, passing inwards, a little forwards, and slightly downwards, and it is also to a certain degree contracted about its middle. For about one-half its length it consists of a prolongation of the cartilaginous and fibrous textures of the auricle. The cartilage, however, does not complete the whole circumference of the canal, but is interrupted on one side, thereby admitting of variation in its diameter. The other half is composed of bone, though in the infant there is merely a ring on which the membrane of the drum is stretched, the bony portion of the tube being subsequently added in the progress of the growth of the skull. The width as well as the tension of this tube are effected by the motions of the jaw; by inserting the finger into its orifice, it will be found to be diminished by shutting, and widened by opening the jaw. This is considered as the reason why the jaw is dropped when a person listens attentively and anxiously, an act which is almost invariably performed under such circumstances. The external integument is prolonged, so as to line the passage throughout, becoming exceedingly thin, and losing its white colour; for about the external half it is pierced by numerous pores, the excretory orifices of the crypts which furnish the wax of the ear. This secretion is of an oleo-resinous nature, of a nauseous odour and taste; qualities admirably suited to the purposes it promotes, those of excluding the entrance of insects, and preserving the canal in a proper condition for the conveyance of vibrations.

Variations in the conditions of the wax may be productive of more or less complete deafness. When deficient, and the ear dry, the hearing becomes imperfect, and still more so when it accumulates so as to plug up the passage, a circumstance of no unusual occurrence, but which admits of an easy remedy. A more serious alteration arises from a change in the character of the secretion, whereby it is rendered thin and purulent. Attempts on the part of rash and ignorant persons suddenly to put a stop to this vitiated secretion have not unfrequently been followed by the most distressing and even fatal consequences.

The Drum.—This is an irregular cylindrical cavity, separated from the external passage by the *membrane of the drum.* Anteriorly a canal leads from it forwards, and a little downwards, to the throat, named the *Eustachian tube.* Posteriorly there are several openings into osseous cells, situated between the two tables of the temporal bone, where the skull bulges out immediately behind the ear, termed *mastoid cells*, and, dividing this cavity from the internal chamber or labyrinth, there is a partition formed of another part of the temporal bone, named the *petrous portion.* In this partition are placed two holes, filled up with membranes, hence named *fenestræ* or *windows*, and, stretching from the membrane of the drum to the oval window, there is a chain of bones, four in number, called the *auditory ossicles.*

Membrane of the Drum.—This membrane is composed of three layers. The external is continuous with the integument lining the auditory passage. The internal constitutes a part of the mucous membrane extended from the throat to the middle ear. Between these two is interposed a fibrous layer, which is the vibratory membrane. Upon this membrane the vibrations conveyed along the auditory passage strike, just as the tambourine is struck by the fingers. By the parts attached to it, it is capable of being rendered more or less tense, in accordance with the strength of the vibrations, and consequently it is calculated to moderate the intensity of the vibrations transmitted to the immediate seat of hearing. The membrane of the drum is however not absolutely essential to the function of hearing, as it is not unfrequently broken without any very material diminution of the function. When this occurs, the individual is capable of blowing through the ear, so as to affect the flame of a candle. Still the perforation of it must render it less capable of adaptation to different sounds. While this membrane preserves its integrity, it is impossible for insects, or other foreign bodies, to gain entrance into the drum, shewing how unfounded must be many of the idle stories respecting such accidents, and how groundless is the apprehension of many respecting them.

Eustachian Tube.—Vibratory oscillations cannot be transmitted through a vacuum, as is sufficiently shewn by the well-known experiment of exhausting the receiver of an air-pump, when neither the ringing of a bell nor the blow of a hammer can communicate sound. It was therefore necessary for an animal destined to hear in the atmosphere that air should be admitted, in order to communicate the vibrations. Had the external air, however, been directly introduced, liable as it is to so many disturbing causes, it might have been productive of much inconvenience, and become the ready source of diseased action. To obviate such disadvantages, the moist air coming up from the lungs, and already assimilated to the temperature of the body, is admitted into the drum by a tube extending from the throat. This tube, first described by an anatomist of the name of Eustachius, from whom it derives its name, proceeds from the forepart of the drum, where it is formed of bone, but soon becomes cartilaginous, and is lined with a mucous membrane continuous with that of the throat. It is about an inch and a half in length, widening from the ear to the throat, like a trumpet. By this passage the air obtains access to the drum, and we are enabled, by holding the nostrils, and inflating forcibly the cheeks, to distend the drum with air, and thus produce such a degree of tension of the membranes as to render the ear insensible to certain tones. By the closure of the mouth and nostrils, and at the sametime making a powerful effort to inspire, the elasticity of the air within the drum is diminished, when the atmosphere causes external pressure, and very low notes become inaudible, though high tones continue to make their impression. The complete obstruction of the Eustachian tube causes deafness; and even a diminution of its calibre, by the swelling of its lining membrane from inflammation, may be productive of temporary dulness of hearing. When deafness arises from complete closure of this tube, hearing may be restored by perforating the membrane of the drum. It is therefore of importance to ascertain whether it proceeds from this or other causes. This may to a certain degree be effected by placing a watch between the teeth of the patient; if the oscillations from its movements are audible, we may be assured that the essential organ of hearing is unaffected, and that the imperfection of the sense depends upon some part of the accessory apparatus. The Eustachian tubes have been considered as subservient to the transmission of sound; but independently of their unfavourable position for this purpose, it would appear from the fact that when partial deafness depends on obstruction of the external passage, the patient hears no better when the mouth is open than when closed, they must act very imperfectly in this way.

In the whale tribe, on the other hand, from the peculiar construction of the blowing tube at the orifice of the windpipe, from the length and narrowness of the auditory passage through the mass of fat over the seat of hearing; and from the great size and wide opening of these tubes into the posterior nostrils of this order of animals, as well as the peculiarities of their circumstances as to sound, vibrations are probably transmitted by this channel.

Mastoid Cells.—The internal surface of the drum is lined throughout with a very thin and delicate mucous membrane, which is likewise extended into cavernous cells placed between the two tables of a portion of the temporal bone. The cavity for the reception of air is thus greatly extended by being prolonged into these cells, and a considerable portion of the internal ear becomes surrounded with an internal atmosphere of its own. We have had occasion to mention that in the elephant the two tables of the skull are separated from each other by a bony cellular structure to the extent of upwards of a foot. These cells have communication with the drums of the ear, so that in this animal a volume of air surrounds the whole head, thereby contributing to the perfection of hearing for which the elephant is pre-eminently distinguished. In the cat tribe, in dogs, and in gnawing animals, there is attached to the drum a hollow sphere of exceedingly hard bone, which, like a conch, is well adapted for reflecting the vibrations of sound, thereby increasing their intensity. In the whale tribe a similar hard conch is found connected with this cavity, very slightly united to any other part of the skull. These various modifications of structure, adapted for the extension of the internal receptacles of air, are thus modified to the circumstances of the animal, each modification undoubtedly being calculated to fulfil the purposes of the function in the most perfect manner. In birds, as in the elephant, the two tables of the skull are separated from each other by air-cells, which not only contribute to the lightness of the head, but also communicate with the drums, increasing the volume of air for the reception of vibration.

Petrous Portion.—It has been stated that hard elastic substances transmit the vibrations of sound with greater velocity and with less diminution of intensity than matter in any other condition. The temporal bone, in which are lodged the principal parts of the apparatus of hearing, has a portion of it composed of bone, of ivory hardness, forming, with the exception of the enamel of the teeth, by far the densest structure in the animal body; from its hard and stony character it obtains the name of *petrous portion*. It is remarkable for its early development, for even in the fœtus its structure is unfolded to a greater extent than that of other bones. The labyrinth, in which is situated the auditory nerve, is completely invested with this petrous bone; it forms the partition between that chamber and the drum, and contributes to the formation of a considerable portion of the walls of the latter cavity. In whales the skeleton is formed of loose spongy bones, with a considerable quantity of oil collected in their cells. To compensate for the softness and sponginess of the bones in general, they have the extremely dense conch attached; and in fishes the organ of hearing is furnished with several small concretions of bone of a smooth and polished appearance, and as hard and brittle as porcelain. These may often be seen in the heads of fish brought to table, their artificial appearance frequently exciting the attention of the curious.

In the partition between the labyrinth and drum, as already mentioned, are two holes closed with membrane, which has suggested the term window, or fenestra, applied to them. The *oval fenestra* has resting upon it one of the bones of the chain of connexion between its membrane and that of the drum, whereby the vibrations are communicated to the labyrinth. The *round fenestra* divides the drum from another part of the labyrinth, and retains the fluids of that cavity.

Auditory Ossicles.—The engraving, representing an outline of the four small bones composing the chain from the membrane of the drum to the oval fenestra, will give a better idea of the appearance of these curiously constructed bodies than the most lengthened description, being here figured of their natural size and relative proportions. *a* has been likened to a *mallet*, *b* to an *anvil*, *c*, from its shape, is termed the *lenticular* or *orbicular*, and *d* is very appropriately designated the *stirrup*.

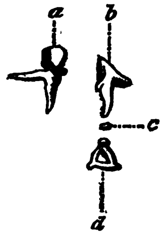

FIG. 35.

As the office that these bones have to execute is peculiar, they are constructed accordingly. Their hardness and brittleness equal those of the petrous portion. The most close examination of their surfaces of connexion fails in detecting, even when aided with magnifying glasses, any thing resembling cartilage upon their articular surfaces, such as in the joints of other bones affords a covering that greatly contributes to lessen friction and diminish the effects of collision. As such effects, however, in the present instance, would be attended with disadvantage, by blunting the intensity of the vibrations, no cartilage, ligament, or synovia enter into the construction of the joints of these little bones, but the dry and polished surfaces are accurately fitted to each other, and the bones united together by an extension of the common lining membrane of the drum, along with the delicate and minute muscles required for their movements. These bones at birth are as large and nearly as dense as at any subsequent period. The *mallet* is attached to the membrane of the drum by its handle, its head resting on a corresponding depression of the second bone or anvil. The *anvil* consists of a body and two branches; to the longest of these branches the minute *lenticular* bone is attached, serving as a small point interposed between the anvil and the head of the fourth bone. The fourth bone or *stirrup* presents a very exact resemblance to the object from which it derives its name: it consists of a head, two branches, and a base—the space substances transmit the vibrations of sound with greater velocity and with less diminution of intensity than matter in any other condition. The temporal bone, in which are lodged the principal parts of the apparatus of hearing, has a portion of it composed of bone, of ivory hardness, forming, with the exception of the enamel of the teeth, by far the densest structure in the animal body; from its hard and stony character it obtains the name of *petrous portion*. It is remarkable for its early development, for even in the fœtus its structure is unfolded to a greater extent than that of other bones. The labyrinth, in which is situated the auditory nerve, is completely invested with this petrous bone; it forms the partition between that chamber and the drum, and contributes to the formation of a considerable portion of the walls of the latter cavity. In whales the skeleton is formed of loose spongy bones, with a considerable quantity of oil collected in their cells. To compensate for the softness and sponginess of the bones in general, they have the extremely dense conch attached; and in fishes the organ of hearing is furnished with several small concretions of bone of a smooth and polished appearance, and as hard and brittle as porcelain. These may often be seen in the heads of fish brought to table, their artificial appearance frequently exciting the attention of the curious.

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between the branches and the base, corresponding to the space for the reception of the foot in a stirrup, is filled up with a very thin and delicate membrane. The base rests upon the membrane of the oval fenestra, to which it corresponds in size and shape.

Several little muscles are attached to these bones, which, by appropriate movements, tend either to relax or tighten the chain, and likewise to moderate the tension both of the membrane of the drum and of the oval fenestra, so that they may be accurately adjusted to the conditions of the sounds they transmit, as the strings of a harp or other stringed instrument are tuned to the required pitch. We thus find in the means adopted for the regulation of the tension of the osseous chain, and that of the two membranes at its extremities, excellent provision for their due adjustment to the various conditions of strength and tone in the undulations of sound they transmit, and perceive how it happens that time is requisite for their adaptation to these conditions, and that a painful and disagreeable impression is produced by the sudden and violent transition from one extremity of the gamut to the other, or from very weak to very loud or strong vibrations. In all this there is a striking analogy between the construction of the ear and the eye. In the last chapter we have seen the means that regulate the quantity of the rays of light permitted to enter the posterior chamber of the eye; and that the disadvantages resulting from the rapid transition from very strong to very weak light, or from very weak to very strong, are so great, that time is required before the eye can accommodate itself to the circumstances. So it s with respect to the ear: the tension of those parts situated in the drum modify the rays of sound before they enter the interior chamber of the organ of hearing, and the sudden transition from very low to very high, or from very weak to very strong vibrations, or conversely, is accompanied with a certain degree of insensibility to them. Thus, a person whose ears have been stunned by the discharge of cannon, remains for some time insensible to weak sounds; as the eye, exposed to strong light, becomes for some time unsusceptible of the impressions of weak light.

According to what has now been stated, the course of vibrations is from the external ear, along the auditory passage to the membrane of the drum; from thence along the chain of bones to the membrane of the oval fenestra, situated in the partition between the drum and the labyrinth,—the latter being the peculiar seat of audition, as the posterior chamber of the eye is the peculiar seat of vision. Sounds, however, may reach the labyrinth by other channels than this, the proper course; and therefore complete deafness does not occur even when the membrane of the drum and the ossicles are totally destroyed, provided the membrane of the oval fenestra remains entire, so that it retains the contents of the labyrinth. Thus, vibrations communicated to the skull are conveyed to the labyrinth directly. Whatever tends to increase the impetus of the circulation may be accompanied with distinct perception of the pulsations of the internal carotid artery, which enters the skull through a canal in the petrous portion of the temporal bone; and when the sensibility of the ear is morbidly augmented, each beat of this artery becomes distinctly audible. When a watch is held in the mouth, without touching the teeth, the ticking is indistinctly heard, but in contact with the teeth it is rendered very perceptible.

The Labyrinth.—This is the proper audience-chamber of the ear. It is entirely surrounded with hard petrous bone, and consists of several intricate winding galleries, which have suggested the name applied to it. Our engraving, representing a view of the labyrinth, magnified, where the different passages are seen laid open, will convey a better idea of the different parts than a detailed description could do. The labyrinth consists of the *vestibule* or lobby, marked *a a a;* of three *semicircular canals*, named, according to their relative position, the *inferior*, *superior*, and *posterior*, the first marked *b b*, the second *c c*, and the third *d d*. Each limb of these canals opens into the vestibule separately. These orifices are marked 1, 2, 3, and 4, excepting one limb of the superior, and another of the posterior, which terminate in a common canal, *e*, opening at 5. The third portion of the labyrinth

FIG. 36.

resembles in form the shell of a snail, from which circumstance it has obtained the name of *cochlea*. The cochlea consists of two spiral canals, which wind round a central pillar two times and a half. These canals are separated by a spiral partition; they communicate however at the summit, where they are covered by what is termed the *cupola*. One of these canals or staircases commences in the vestibule, and ascends spirally to the cupola, marked *h h h h h*. The other, *g g g g*, may be considered as commencing at the cupola, descending till it terminates at the round fenestra of the drum, from which it is separated by the membrane of that orifice.

This intricate and curiously constructed part of the apparatus of hearing is lined throughout by a membrane which secretes a somewhat viscid and limpid fluid, in which terminate the delicate pulpy extreme divisions of the auditory nerve, somewhat in the same manner as the retina is spread out upon the choroid coat of the eye. Besides, there are little vesicles filled with a transparent fluid, much smaller in their diameters than the several canals they occupy. These fill up the central spaces, and may be compared to the vitreous humour of the eye, serving to support the delicate auditory nerve, as that supports the expanded retina. At the same time, they are admirably fitted for receiving and communicating the vibratory impressions to the nervous fringes. It has been supposed that the use of that canal of the cochlea, which terminates at the oval fenestra, is to admit of the undulation of the fluid contents of the labyrinth, where the vibrations communicated through the oval fenestra circulate along the winding passages, pass up the spiral staircase of the cochlea, leading from the vestibule to the cupola, and from the cupola down the other staircase to the round fenestra, the membrane of which yields to the impulse, and again, by its elasticity, returns the vibration in the opposite direction.

The fifth cranial nerve, associated with filaments from the facial nerve, contribute the nervous twigs to the internal ear; the former imparting common sensibility to the different parts, as the filaments from the same nerve send branches to the interior of the eye for a similar purpose; the latter commanding the movements of the muscles of the chain, so as to bring them into action with due force in the necessary state of combination, and likewise supplying the muscles of the auricle. Thus we find the peculiar sensibility of the ear depends on the auditory, the common sensibility on the fifth, and the voluntary and instinctive movements on the facial, nerve.

Fig. 37 is intended to convey a general idea of the relative position of the different parts of this interesting organ, which we have endeavoured to describe. *a* is the pavilion of the external ear, *b* the lobe, *c* the external auditory passage, *d* the membrane of the drum, *e* the cavity of the drum, *f* the Eustachian tube, *g* the oval fenestra, *h* the round fenestra, *i* the vestibule, *k* the cochlea, *l* the auditory nerve, on its passage to the labyrinth, M the semicircular canals.

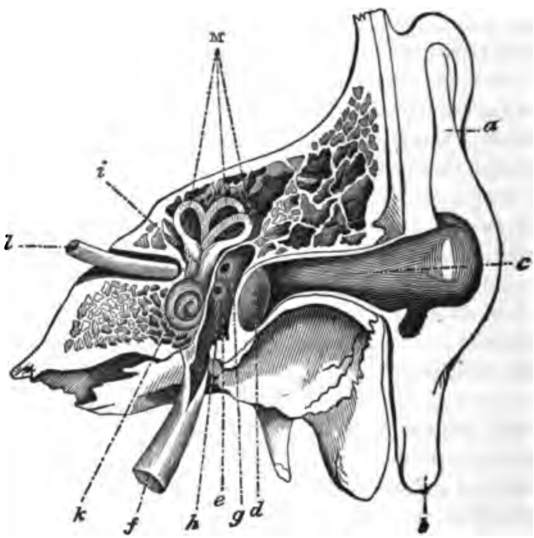

FIG. 37.

From what has been stated, it will be perceived that every part of this delicate instrument combines with every other with the utmost nicety and accuracy; that the pavilion is constructed for the reception and transmission of vibrations from without to the drum, where they are subjected to various modulations, and subsequently conveyed to the labyrinth, the immediate seat of the auditory nerve; that from this chamber the impressions from the vibrations are communicated backwards to the origin of the auditory nerve, at the posterior surface of the medulla oblongata, the centre of the cerebro-spinal portion of the nervous system; and lastly, that they become objects of perception to the mind through the medium of the cerebrum. But how they should impress the delicate extremities of the auditory nerve, how they are conveyed by it to the brain, or of what nature is the communication between the matter of the brain and the mind, we are entirely ignorant, and in all probability, in our present state of existence, will ever remain so.

In vain also shall we attempt to account for the pleasurable sensations derived from the various combinations of sound which constitute music,—music being one of those combinations of material and mental conditions from which we, in our material and mental relations, derive more or less gratification according to our individual characters. It will be time enough for us to explain, by material causes, how one person is so sensibly affected by music to which another, under the same apparent circumstances, seems to be altogether indifferent, when we become able, on material principles, in a satisfactory manner, to account for peculiarities which distinguish the individuals of the human race. It is sufficiently well known that the gratification arising from music depends to a very considerable extent upon association of ideas, on education, and even upon transient, accidental, and apparently trivial circumstances, the investigation of which is more calculated to gratify the fancy than improve the judgment.

CHAPTER X.

TOUCH.

General Observations on Touch—Its Universal Diffusion over the surface of the Body—External Integuments—The Scarf-skin, forming the barrier between the living and the dead—The Mucous Web, the especial seat of Colour—Albinos—Remarkable case of a dark Hindoo becoming fair—True Skin, that of which Leather is made—Its External Surface the immediate seat of the Sense of Touch—Tact and Touch—All parts not equally susceptible to the impressions of Touch—Informs us of the condition and properties of External Objects—The most important Guardian of the Body—Less liable to be imposed upon, and to bear false witness, than the other Senses—The confidence placed in it—The superiority enjoyed by Man in the excellency of this Sense—Case of J. Mitchell, born Blind and Deaf.

By sight and hearing we become cognizant of the existence of distant objects, and we have seen how admirably the instruments are constructed for affording us the information they are destined to communicate, and how accurately they accommodate themselves to the varying conditions of the causes which excite these respective sensations. By means of touch we are informed, in the first place, of the form and size of objects, and of the resistance they offer, thereby giving ideas of smoothness, roughness, hardness, softness, and weight. In the majority of these instances, if not in all of them, the sensation communicated results from the combined impression made on the surface of the organ brought in contact with the object, and the degree of muscular effort necessary to oppose or overcome the resistance presented. Secondly, by the same sense we are able to judge of the differences between the temperature of external objects and that of our bodies, which excite in us the feelings of heat and cold. Self-preservation depending more immediately on this than any other sense, the faculty is not limited to any particular situation, as is the case with the other senses, but it is diffused generally over every part exposed to external influences. The skin, however, is especially endowed with the susceptibility to impressions which originate the sensations of touch, and in this respect it varies in different situations, some parts, from a favourable combination of structure, being better adapted for receiving and transmitting accurate and definite sensations than others.

We have already had occasion to take under our consideration the external integuments, in so far as they exercise the functions of secretion and absorption, and have now to examine them in reference to the function of touch. The external integuments consist of three layers, which require special notice, namely, the *cuticle*, *mucous web*, and *true skin*.

The Cuticle, or Scarf-skin, forms the external investment of the body, and varies in its texture and thickness in different parts. It does not present any particular organization, nor have blood-vessels or nerves been traced in its structure, but it appears to be the product of the subjacent vessels. These vessels pour out an albuminous secretion, which, by the influence of the air, becomes converted into the cuticle—a change similar to that which takes place in the coagulation of the white of an egg. The cuticle then may be considered as an indurated pellicle, serving as a barrier between the living parts of the body and all that is external to it. It varies very much in thickness and consistence in different parts, according to the condition of the subjacent vessels from which it is derived, and forms an exact mould of the surface which it covers. From its being translucent, the colour of the parts beneath shine through it, though from its not being perfectly transparent, the tints are somewhat modified by their transmission. When the surface of the body is exposed to irritation, the vessels that pour out the lymph, from which the cuticle is derived, have their action increased, and the cuticle either becomes thickened, as in the palms of the hands and soles of the feet, or the effusion is so abundant as to cause a separation between it and the true skin, producing blisters. The thickening of the cuticle from pressure affords one of the innumerable examples of design which the construction of the animal body so admirably displays. Had this tissue been subject to the general law, in virtue of which pressure excites absorption, as exemplified in the internal organs under various diseased and other conditions, it should have been rendered thinner, and consequently less capable of affording due protection under the very circumstances where protection is most necessary; but instead of this, pressure causes the cuticle to become thicker and more dense, that it may serve as a shield to the parts it covers. It is perforated by millions of minute pores, which allow of the escape of the matter of transpiration, and of the sebaceous secretion. It is constantly being renewed from the internal surface, and as constantly peeling off from the external surface, in a fine powder, or in thin scales. After some diseases, as scarlet fever, and other affections in which the integuments are much involved, it is often completely renewed, the old scarf-skin being thrown off in large patches.

The cuticle is present in all organized beings, plants as well as animals, though it presents, as may be readily supposed, great diversities in appearance and structure, according to the rank of the object for which it serves as a protection. In many reptiles and crustaceous animals it is cast off at certain periods in one mass, when it presents an exact mould of their bodies, their scales and other external parts being exactly represented.

The Mucous Web.—Immediately under the scarf-skin is situated a soft pulpy network, exceedingly thin in the fair European, but much more apparent in the dark-coloured races, especially in the Negro. It appears to consist chiefly of the shaggy extremities of blood-vessels, interlaced and bound together by delicate filaments of cellular membrane. This is the immediate seat of colour, the colouring matter, consisting of minute globules, varying in their tints in the different races;—even the different nations of Europe are characterized by the colour of their skin. It has been supposed that the colour of the skin depends upon the intensity of heat and light to which the body is exposed. It is true, that in tropical countries, the colours of both plants and animals are more intense and brilliant than in colder regions, and that exclusion from light produces a pale blanched appearance, while exposure to it has a contrary tendency; but the variations thus produced in the colour of the skin are neither permanent nor do they descend to the offspring. In every variety of the human race, as well as in the lower animals, examples occasionally happen where the mucous web is totally devoid of colour, such individuals being termed *Albinos*. Their skin has a somewhat disagreeable deadly white appearance; their eyes are blood-red, from the absence of colour in the iris and choroid membranes, and their hair is also colourless. These accidental occurrences are not easily accounted for, though apparently they have a tendency to run in families; and it is possible, that by attention to breeding in and in, a permanent variety might be established. At Lasswade, a village five miles from Edinburgh, there is a family of seven children, two of which are albinos, a male and a female. The parents, and particularly the father, were what would be termed swarthy; the other brothers and sisters are also dark-complexioned. In every respect they enjoy ordinary health and strength, but are less able to tolerate strong light, though they do not see better than others in obscure light. A few years ago, there was a very remarkable instance in Edinburgh of a

Hindoo, advanced in life, who came over to this country when a boy. At an early period of manhood, white spots began to appear on different parts of the skin, which, in progress of time, gradually enlarged, so as ultimately to spread over by far the greater part of his body, leaving on the face a few black spots, as also a few patches on the trunk and limbs. In this case, the colouring matter of the mucous web was not entirely removed, but merely replaced by globules of a whiter colour. I attended this individual during his last illness, and afterwards examined the body, whereby an opportunity was afforded for obtaining a portion of his spotted skin, which was carefully examined, without being able to ascertain the cause of this curious change. He was well known in Edinburgh, and must still be in the recollection of many, as his case excited some curiosity among medical men, as well as others. The white portion of his skin was as fair as that of the majority of Scotchmen, and the spots as dark as the skin of the darkest of the Hindoo races. He was married to a Scotchwoman, and had a family as fair as their mother, but with the Hindoo features so well marked as not to be mistaken.

The Dermis or True Skin.—This is the thickest and most important part of the external integuments. It is composed of an infinite number of plates, consisting of filaments inextricably interwoven together, and abundantly furnished with blood-vessels and nerves. Externally, its texture is most dense, becoming softer and looser, and gradually passing into the common cellular tissue beneath. Its thickness varies in different parts of the body, as also according to the age and sex of the individual. On the back it is nearly twice the thickness that it is on the anterior surface of the body, and much thicker on the outside of the limbs than on their inner surfaces. It is chiefly composed of animal gelatin, and by being combined with the vegetable principle named tannin, becomes converted into leather. It is everywhere perforated by numerous pores, which give transmission to the oily or sebaceous secretion, by which its softness, smoothness, and flexibility are preserved.

Its external surface is everywhere studded by exceedingly minute nipples or papillæ. In several parts, as in the palms of the hands, and extremities of the fingers, these are disposed in regular symmetrical rows, forming waving lines, and separated by small crevices that admit of the flexions of the skin, and of its adaptation to the surfaces of external objects. The papillæ are plentifully supplied with blood-vessels, which are so constructed as to allow of a congestion or accumulation of blood in them, whereby they swell and become erect, consequently the nerves are rendered more susceptible to impressions. The readiness with which the external surface of the skin admits of an increased quantity of blood is strikingly displayed in the act of blushing, and in various other conditions.

The immediate instruments of touch are the extremities of the sensiferous nerves terminating in the papillæ on the surface of the body. The object, the properties of which it is the office of these nerves to communicate to the mind, does not come immediately in contact with these; both the cuticle and mucous web being interposed, the removal of which, by blisters or otherwise, does not increase the sense, but tends to destroy and disturb it. From this arrangement, impressions are transmitted through the insensible scarf-skin, by the hairs, and through the nails. The whiskers of many animals, such as the cat tribe, are subservient to touch, nerves being situated at their roots that are highly susceptible of such impressions. Even by the hard and insensible hoofs of animals, sensations are communicated to the subjacent nerves, as may be witnessed when the highland pony exercises his sagacity in ascertaining the soundness of a moorland path by beating it with his hoof before trusting his weight upon it.

Tact and Touch.—This, as well as the other senses, may be regarded under two conditions. In the one, where the attention is especially directed to the impressions received from the sense, and a voluntary effort made to bring it into the most favourable state for the exercise of its function; in the other, the mind is not particularly roused in order to receive distinct perceptions from the sensations communicated from the seat of impression. The former may be held as the active, and the latter as the passive condition of the senses. Thus, with respect to vision, when we call the eyes actively into operation we *look;* but in their passive condition we only *see.* As also in audition, actively, we *listen;* passively, we *hear.* So likewise, in regard to taction, when we exercise it in the active state, we touch; while in its passive condition we have merely tact.

All parts of the surface of the body are not equally susceptible to the impressions of touch. The extremities of the fingers and toes are admirably constructed for the exercise of this sense. The nerves proceeding to these parts are comparatively very large, and almost entirely distributed upon the papillæ. They are accompanied with large blood-vessels, which readily admit of a varying quantity of blood, according to the conditions required for the due exercise of the function. They are supported upon cushions, which, by their fulness and elasticity, adapt them to the form and consistence of objects brought in contact with them, and they are protected by the broad shield-like coverings, the nails. The lips and tongue are likewise delicate instruments of touch, and appear to be the first employed for that purpose. The infant probably first experiences sensations from this sense on being applied to the breast, and there can be no doubt that the gratification enjoyed by the mother and her offspring is mutual, in giving and receiving that bountiful provision destined by providence for the nourishment of the new-born of the highest class of animals.

The infant having thus learned first to cultivate and receive impressions of touch in the lips and tongue, continues for some time to rely with greater confidence on the evidence obtained from this than any other source, and accordingly persists in carrying every object to the mouth, in order to subject it to their scrutiny, till the hands and fingers become sufficiently educated and manageable to serve as substitutes for them.

Sir Charles Bell states, in his Bridgewater Treatise, that the tongue is incapable of perceiving the pulsation of the artery at the wrist. This may be the case with some individuals, but it is certainly not universally true, for I myself can distinctly feel and count my own pulse at the wrist by the tongue, though more perceptibly when it rests upon the teeth. The pressure of the cushions on the small bones at the extremities of the fingers, on which they rest, contributes to the sense of touch. When we examine solid bodies, the teeth are excellent instruments for this purpose in the examination of very hard substances. Liquids, on the other hand, are accurately judged of by the soft and pliable tongue.

In the same treatise he contends for the existence of a sixth sense, which he terms the muscular. It may be doubted, however, whether his arguments are sufficient to induce one to acquiesce in the propriety of considering the muscles as endowed with a distinct sense, apart from their peculiar sensibility; and if the peculiar sensibility which they undoubtedly possess be sufficient to be considered as a distinct sense, upon the same grounds there would arise the necessity of still further multiplying the number of senses; for the lungs, alimentary canal, urinary organs, and others, have each peculiar sensibilities and endowments adapted to the functions they have to perform. Muscular action is necessary to the proper exercise of the sense of touch, enabling us to estimate the resistance which bodies offer, and thereby to judge of their consistence and weight, their smoothness and roughness, and their size and form. By touch we also obtain ideas of time, number, and space.

Constructed as we are for existence in an atmosphere which is subject to constant and sudden variations of temperature, and liable as we are to have heat either imparted or extracted from our bodies with such rapidity or in such a quantity as to be inconsistent with our safety and preservation, it became absolutely necessary that we should be furnished with the means of being warned to withdraw or protect ourselves from objects calculated to affect us in a dangerous manner in these respects. Nowhere could this safeguard be placed so conveniently and so advantageously as in the integumentary coverings. The special sensibility, therefore, resident in the skin, not only furnishes us with a knowledge of the geometrical characters of external substances, and the resistance they offer, but likewise informs us of the presence of dangers which may surround us; and by the pain which may be excited, forcibly admonishes us to avoid the causes which originate it.

Man enjoys, in the exquisite sensibility of his skin, a superiority in the sense of touch which he does not possess in the other senses, many animals surpassing him in one or other of the rest. In this, however, he stands unrivalled. His beautiful and admirable instrument, the hand, is by him employed chiefly in connexion with touch, and for this purpose it is altogether unequalled in the whole of the animal creation. Even in those animals which make the nearest approaches to him in their organic structure, the corresponding organ is employed for locomotion. He alone reserves it for higher and more delicate operations. So evident are the many advantages derived from the hand, and so great the superiority to which he is indebted to it, that some philosophers have not hesitated to ascribe to this cause the preeminence he has over his fellow-creatures, forgetting that man's pre-eminence does not by any means altogether spring from the construction of his body, admirable as it is, but from that body being the associate of a rational spirit, which discovers and exercises the capabilities and powers of the instruments entrusted to its use.

Instead, then, of the delicacy and tenderness of the skin of man being a disadvantage, it is the source of some of his most exquisite physical enjoyments, and the means of his obtaining accurate knowledge of the properties of the external world around him. Sight, hearing, and touch, are justly entitled to be considered as the intellectual senses. They are the means through which we obtain our most valuable information—the witnesses that furnish the evidence of the existence of external things. Where they agree in the evidence they deliver, we cannot for a moment doubt of the truth of their report. Individually, however, they are liable to receive erroneous impressions. Sight is liable to many illusions; so likewise is hearing. Upon the whole, perhaps touch is the least subject to deception; accordingly we rely upon its testimony with greater confidence than on any of the others. It is important to know that the fact of the greatest and most paramount interest of all others to mankind, the resurrection of the Saviour, is established on the evidence of the three intellectual senses. That such evidence was afforded we are assured on several occasions, particularly on the following, recorded by St John:—" But Thomas, one of the twelve, called Didymus, was not with them when Jesus came. The other disciples therefore said unto him, We have seen the Lord. But he said unto them, Except I shall see in his hands the print of the nails, and put my finger into the print of the nails, and thrust my hand into his side, I will not believe. And after eight days again his disciples were within, and Thomas with them: *then* came Jesus, the doors being shut, and stood in the midst, and said, Peace *be* unto you. Then saith he to Thomas, Reach hither thy finger, and behold my hands; and reach hither thy hand, and thrust it into my side: and be not faithless, but believing. And Thomas answered and said unto him, My Lord and my God. Jesus saith unto him, Thomas, because thou hast seen me, thou hast believed: blessed are they that have not seen, and *yet* have believed." Thus the incredulity of the Apostle Thomas has furnished to all succeeding ages a remarkable instance of the graciousness of our Saviour, and of an opportunity afforded to the sense of touch to bear testimony as to the reality of the resurrection of his body.

The excellence of the sense of touch, has led some to consider that the erroneous impressions to which the other senses are liable are corrected by it. Strictly speaking, however, the senses cannot correct each other, since the sensations they communicate to the mind are of a different character. The eye can convey no idea of sound, nor the ear of colour, nor can the touch furnish impressions of either the one or the other. It is true, that where necessity has called forth the powers of the sense of touch, as in the blind, the accuracy with which they are enabled to judge of the properties of bodies is truly astonishing to those who enjoy the use of all the senses, and can select one or another for obtaining information respecting external objects, as may best suit their purpose. But where the evidence is chiefly or entirely to be derived from one sense, and where it is frequently called into operation, and much attention paid to its reports, its capabilities become vastly increased. Dr Sanderson, Professor of Mathematics at Cambridge, and who was blind from the second year of his age, could distinguish false from true medals. Rudolphi mentions the case of Baczko, who could distinguish cloth of equal quality, but of different colours: black appeared to him among the roughest and hardest; to this succeeded dark blue and dark brown, which he could not distinguish from each other; neither could he distinguish the colour of cotton or silk stuffs. There are many other remarkable instances of the wonderful delicacy reached by this sense from its cultivation by the blind. But in all such cases there merely exists a greater degree of perfection in the exercise of its own powers, not an assumption of the peculiar function belonging to the others.

Even the touch is liable to error in some instances. If two fingers are crossed over each other, and a pea rolled between them, we receive the impression of the presence of two distinct objects, though we very well know that there exists only one: nor does sight in this instance remove the deception. However, in this case the organs are placed in an unnatural position, and there is every reason to believe, that by continuing the practice for a length of time, the illusion would vanish. A fallacy to which touch is much more subject, occurs with respect to heat. Thus, if we place the hand in separate vessels, the one containing warm, and the other very cold water, and after some time withdraw the hands, and immediately plunge them into the mixture of both waters, to the one hand the mixture appears warm, and to the other cold. Or, in a tropical country, if one person descends a high mountain from the region of perpetual snow, and meets at the middle of the descent another ascending from the burning valley at its base, he who is descending may feel oppressed with heat, while the other is shivering with cold, though both sensations are produced by the same temperature. Frozen mercury excites the same sensation, when touched by the finger, as is experienced from the contact of red-hot iron.

It is almost impossible to conceive an individual totally deprived of touch, though numerous cases daily occur of individuals deprived of it in particular parts from paralysis. Numerous instances of deprivation of one of the two other noble senses, sight and hearing, are constantly presented to us. There are also melancholy examples recorded, where unhappy individuals have been destitute of both, but fortunately they are of rare occur-

Hindoo, advanced in life, who came over to this country when a boy. At an early period of manhood, white spots began to appear on different parts of the skin, which, in progress of time, gradually enlarged, so as ultimately to spread over by far the greater part of his body, leaving on the face a few black spots, as also a few patches on the trunk and limbs. In this case, the colouring matter of the mucous web was not entirely removed, but merely replaced by globules of a whiter colour. I attended this individual during his last illness, and afterwards examined the body, whereby an opportunity was afforded for obtaining a portion of his spotted skin, which was carefully examined, without being able to ascertain the cause of this curious change. He was well known in Edinburgh, and must still be in the recollection of many, as his case excited some curiosity among medical men, as well as others. The white portion of his skin was as fair as that of the majority of Scotchmen, and the spots as dark as the skin of the darkest of the Hindoo races. He was married to a Scotchwoman, and had a family as fair as their mother, but with the Hindoo features so well marked as not to be mistaken.

The Dermis or True Skin.—This is the thickest and most important part of the external integuments. It is composed of an infinite number of plates, consisting of filaments inextricably interwoven together, and abundantly furnished with blood-vessels and nerves. Externally, its texture is most dense, becoming softer and looser, and gradually passing into the common cellular tissue beneath. Its thickness varies in different parts of the body, as also according to the age and sex of the individual. On the back it is nearly twice the thickness that it is on the anterior surface of the body, and much thicker on the outside of the limbs than on their inner surfaces. It is chiefly composed of animal gelatin, and by being combined with the vegetable principle named tannin, becomes converted into leather. It is everywhere perforated by numerous pores, which give transmission to the oily or sebaceous secretion, by which its softness, smoothness, and flexibility are preserved.

Its external surface is everywhere studded by exceedingly minute nipples or papillæ. In several parts, as in the palms of the hands, and extremities of the fingers, these are disposed in regular symmetrical rows, forming waving lines, and separated by small crevices that admit of the flexions of the skin, and of its adaptation to the surfaces of external objects. The papillæ are plentifully supplied with blood-vessels, which are so constructed as to allow of a congestion or accumulation of blood in them, whereby they swell and become erect, consequently the nerves are rendered more susceptible to impressions. The readiness with which the external surface of the skin admits of an increased quantity of blood is strikingly displayed in the act of blushing, and in various other conditions.

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rence. A case of this kind which excited great interest some years ago in the Royal Society of Edinburgh, is detailed in the 7th and 8th Vols. of their Transactions. The case is so well calculated to shew the vast superiority of the intellect of man under peculiarly unfavourable circumstances, and to display the excellency of the immaterial part of his constitution, even when deprived of information through some of the most essential material channels, that we shall select a few of the instances of the state of this individual. James Mitchell, the subject of the following account, was the son of a respectable parish minister in the county of Elgin. He was blind from birth, in consequence of opacity of the cornea, though the iris displayed susceptibility to light. He was also completely deaf, and consequently dumb. He had the advantage of affectionate and intelligent parents, and was happy in the possession of an amiable and judicious sister, to whom he appears to have been much indebted. "His mother, who is an intelligent and sensible lady," says the Rev. Professor Glennie, "very early discovered his unfortunate situation; she noticed that he was *blind*, from his discovering no desire to turn his eyes to the light, or to any bright object; and afterwards (in his early infancy also) she ascertained his being *deaf*, from the circumstance that no noise, however loud, awakened him from sleep. As he grew up, he discovered a most extraordinary acuteness in the senses of touch and smell, being very soon able by these to distinguish strangers from the members of his own family, and any little article which was appropriated to himself, from what belonged to others. In childhood, the most noticeable circumstance relating to him, was an eager desire to strike upon his fore-teeth: this he would do for hours." * * *

"His countenance, notwithstanding his unfortunate defects, does by no means indicate fatuity; nay, the lineaments (in church, for instance, and during the time of family prayer) are perfectly composed and sedate;

when sensible of the presence of a stranger, or of any object which awakens his curiosity, his face appears animated; and when offended or enraged, he has a very marked ferocity of look. He is (for his age) of an athletic form, and has altogether a robust appearance.

"He behaves himself in company with much more propriety than could be expected,—a circumstance owing undoubtedly to the great care of his parents, and of his elder sister. He feeds himself. When a stranger arrives, his smell immediately and invariably informs him of the circumstance, and directs him to the place where the stranger is, whom he proceeds to survey by the sense of touch. In the remote situation where he resides, male visitors are the most frequent, and, therefore, the first thing he generally does, is to examine whether or not the stranger wears boots; if he does wear them, he immediately quits the stranger, goes to the lobby, feels for, and accurately examines his whip; then proceeds to the stable, and handles his horse with great care, and with the utmost seeming attention. It has occasionally happened that visitors have arrived in a carriage, and on such occasions he has never failed to go to the place where the carriage stood, examined the whole of it with much anxiety, and tried innumerable times the elasticity of the springs. In all this he is undoubtedly guided by the smell and touch only." * * *

"The feeling by which he appears to be most powerfully actuated (at least to a stranger), is curiosity, or an anxious desire to make himself acquainted with every thing that is new to him. He appears to feel affection for his family very strongly: discovered extreme sorrow on account of his father's death. * * * He is likewise capable of feeling mirth, and frequently laughs heartily. He is highly gratified by getting new clothes; and as tearing his clothes is the most usual expression of his anger, so the punishment he feels most is to be obliged to wear them after he has torn them. He is subject to anger after being crossed in any of his desires, or when he finds any of his clothes, or articles with which he amuses himself, removed from the chest in which he keeps them." * * * "When he is hungry he approaches his mother or sisters, touches them in an expressive manner, and points towards the apartment where the victuals are usually kept. If he wants dry stockings, he points to his legs, and in a similar way intimates his wishes upon other occasions. A pair of shoes were lately brought to him, and on putting them on he found them too small. His mother then took them and put them into a small closet. Soon after a thought seemed to strike him; he contrived to obtain the key of the closet, opened the door, took the shoes, and put them on the feet of a young lad who attends him, whom they suited exactly." * * *

"When he is sick and feverish, which sometimes happens, he points to his head, or takes his mother's hand and places it opposite to his heart, seemingly with an intention that she may observe its beating more quickly than usual. He never attempts to express his feelings by utterance, except when angry, when he bellows in a most uncouth manner. Satisfaction or complacency he expresses by patting the person or object which excites that feeling. His smell being wonderfully acute, he is frequently offended through that sense, when other persons near to him smell nothing unpleasant; he expresses his dissatisfaction on such occasions by putting his hand to his nose, and retreating rapidly. His taste seems also to be exquisite, and he expresses much pleasure by laughing and smacking his lips when savoury victuals are laid before him.

"His father, when alive, was at much pains in directing him, as his mother still is; but his elder sister seems to have a much greater ascendency over him, and more power of managing him than any other person. Touching his head with her hand seems to be the principal method she employs in signifying her wishes to him respecting his conduct. This she does with various degrees of force, and in different manners; and he seems readily to understand the intimation intended to be conveyed. In short, by gratifying him when he acts properly, and withholding from him the objects of his complacency when he has done amiss, he has been taught a sense of what is becoming in manners, and proper in conduct, much stronger than it could be otherwise believed that any person in his singularly unfortunate situation could acquire."

Several further details are given of this interesting case in the above transactions, by the late Professor D. Stewart, Dr Gordon, lecturer on physiology, Sir James Mackintosh, Miss Mitchell, and others. The extracts now cited from Professor Glennie's account may, however, suffice to shew the display of character evinced under such remarkable and fortunately rare circumstances. Another case is detailed in Hibbert's Description of Shetland, of a lad born blind and deaf, but he appears to have been at the same time idiotic, so that the case is not calculated to afford the same interest to the general reader.

CHAPTER XI.

SMELL AND TASTE.

Intimate connexion between Smell and Taste—Not of much importance as Intellectual Channels. SMELL.—The Nostrils—Confidence reposed in Smell by several of the Lower Animals—Its excellence in the Dog—Smell in Vultures—In the Raven—In Fishes—Odours—Gratification derived from Odours influenced by Constitution, Habit, &c.—Classification of—Permanence, Extent, and Divisibility of—Morbid Conditions. TASTE.—Seat of—Papillæ of the Tongue—Savours—Classification of—Influence of Habit—Acquired Tastes—Affected by the State of the Stomach—Morbid Conditions—Gustatory Organs in different Classes of Animals—The Condition of Matter necessary to excite Taste.

THE senses of smell and taste may, to a certain extent, be considered in connexion. Their respective functions have a reference to digestion, and are in some measure subservient to it. They are more closely associated than any of the other senses, and under some circumstances their co-operation is essential to the due performance of their office. Thus, when the nostrils are obstructed, taste is considerably impaired, and pleasurable or disagreeable sensations produced by many substances depend on a combined result of the impressions on the organs of smell and taste. Neither of them are of much importance as intellectual organs in civilized life, therefore they are not much cultivated; indeed, much attention to their gratification is held as being in an especial manner sensual, and rather to be avoided than indulged in. This ought to refer, however, only to their abuse, and not to their proper and legitimate use. None of our faculties are to be despised or neglected because they may be wrongfully employed, or rendered subservient to the degradation of individuals. Smell is useful to the apothecary, the chemist, and the perfumer, and taste to the two former of these, as well as to the wine-taster, the grocer, the tea-taster, &c.

SMELL.

Of the fourteen bones which enter into the formation of the face, only three are excluded from forming a part of the cavities of the nostrils, namely, the two cheek bones and the lower jaw. Three of the eight bones of the cranium likewise constitute a part of the nose. Several of these are extremely light and spongy in their texture, and are curiously convoluted and laminated, so as to present a very extensive surface, especially in animals remarkable for the acuteness of their scent. In the seal, for example, the external surface of the nose has been estimated as equal to 240 cubic inches. The two bones of the upper jaw form a considerable portion of the nose; from each a process projects upwards, and ascends to join the frontal bone. Upon these processes rest two small bones, named *nasal*, which are united with each other, and form the bridge of the nose, the two upper jaw-bones serving as abutments to the arch. The internal bones are extremely delicate and spongy. Their laminated and convoluted structure has suggested the idea of a Turkish turban: hence they are termed turbinated bones. In connexion with the nostrils, especially in the adult, there are several cavities, as in the frontal and upper jaw-bones, that are called sinuses. These sinuses considerably extend the surface on which the lining membrane is expanded, and contribute to the perfection of the function, by affording capacious receptacles for air, loaded with odorous particles. The nose is divided by a central partition into the two symmetrical organs, the nostrils, in the same manner as are all the other organs in the body which are placed in what has been named the median plane, as the mouth, tongue, larynx, &c. Besides the bones, there are cartilages which enter into the formation of the nostrils; one of these completes the central partition, two others extend from the lower margin of the nasal bones, and two lateral cartilages form the wings of the nostrils. These elastic bodies readily admit of motion and modification of shape in the nose; at the same time they contribute to its form and shape as characteristic of the individual, or of the race. In some animals these cartilages are largely developed, as in the elephant, in the formation of the proboscis, an instrument of varied powers, and applicable, under the control of the will, to a great variety of purposes. Attached to the cartilages there are several muscular fibres for the movement of the nostrils, for regulating the external orifices in accordance with different conditions of respiration, and for enabling us to exercise the sense of smell with greater effect when we wish voluntarily to employ that function.

The lining membrane of the nose belongs to the class of mucous membranes, and from the anatomist who first gave a particular description of it, it is known by the name of the Schneiderian. From being the source of the phlegm or mucus of the nose, it is likewise termed pituitary membrane. This membrane is prolonged into all the cavities connected with the nostrils, and over the whole of the laminated folds of the spongy bones. Externally it is continuous with the common integuments, and posteriorly with the lining membrane of the throat. It differs in its appearance and thickness in different situations. Where it constitutes the immediate seat of smell it is thicker, more vascular, and of a redder colour than mucous membrane in other situations; but where it is extended into the sinuses, it becomes thin, pale, and of a smooth surface. The thick vascular portion is covered with a shaggy filamentous nap, like the pile of velvet, amidst which there are scattered numerous little mucous crypts that yield the secretion with which it is chiefly moistened, though it is also bathed with the tears that, after having washed the external surface of the eye, are conveyed by the nasal ducts to be diffused over the internal surface of the nose, in order to dilute the thick viscid mucus. The blood-vessels of this part are exceedingly numerous, and present a very curious modification of distribution. The nerves, as we have already seen, are derived from three sources. The first pair, or olfactory, are limited to the thick vascular portion, and constitute the immediate channels for the transmission of odorous sensations to the brain. Twigs from the first and second branches of the fifth are plentifully ramified over the whole expanse of the pituitary membrane, imparting to it common sensibility. Lastly, there are branches from the facial, to regulate the action of the muscles.

The apparatus of smell presents great diversities in different tribes of animals, some of the class mammalia placing more confidence in it than all their other senses taken together. This is remarkably the case with ruminants, as oxen, sheep, deer, and antelopes. The shepherd occasionally avails himself of it, when a lamb has died, and he wishes to put to the ewe another lamb that may have lost its dam; if she refuses to foster the stranger, he is sure to succeed by stripping off the skin of her own offspring and tying it on the back of the stranger, that she may smell the skin; she then entertains and treats it as her own. In this case she neglects the sense of sight, for nothing can be more uncouth than the new object of her affections; neither does she attend to the evidence afforded by hearing; however unlike the bleating of the foster lamb may be to that to which she was first accustomed, her smelling is satisfied, and she is content. The same practice succeeds with the cow. Such are termed in Scotland *tulchan* lambs and *tulchan* calves. When the lay nobility seized on the property and dues of the church at the Reformation, and the people began to demur paying tithes of many things previously paid to the clergy, they employed agents to enforce their collection: these agents the people nicknamed *tulchan bishops*, thereby strongly indicating the estimation in which they held them.

The final purpose why these animals should be endowed with an acute and delicate smell is sufficiently obvious: they have to select their food from amidst a variety of plants, many of which are possessed of highly deleterious properties, whereby they might readily be poisoned, were they to take them along with their food. Accordingly, we find their olfactory nerves are larger than any of the others connected directly with the brain. The cavities of the nose are very capacious, the surface of the pituitary membrane vastly extended, and the orifices placed in the convenient vicinity of the mouth, that every thing may be submitted to this highly developed sense before it is taken up to be introduced to the organs of digestion. The elephant, the tapir, and the hog, have an acuteness of scent corresponding to the great extent of the apparatus. The latter animal is employed in France to hunt for truffles, a species of mushroom which vegetates at a considerable depth under the surface, but not beyond the reach of the sense of smell of the pig. When laid on upon ground adapted for this kind of hunting, the pig soon ascertains where the truffle is situated, and by his powerful snout would soon unearth and devour it, if not restrained by the sportsman, who immediately proceeds to dig for the treasure, and appropriates it to himself.

In carnivorous quadrupeds the organ of smell is also fully developed. Its accuracy and delicacy in the dog, for example, are too well known to require any argument to prove them. The certainty with which he detects the footsteps of animals, long after they have been imprinted, is truly astonishing; as is the facility with which he traces the progress of his master through crowded streets, distinguishing the emanations which his foot, defended by stockings and shoes, has left on the surface, and recognising them, moreover, amidst thousands of odorous particles, not only of different kinds, but of different individuals of the same species. In like manner he selects, and pertinaciously pursues an individual from a herd or from a flock, and however anxiously his prey may seek protection amidst its fellows, he unhesitatingly continues to follow its track, guided by his scent. Such acuteness and perfection in this sense, which exists in man only comparatively in a very obtuse state, is truly marvellous.

In the whale tribe, if the sense exists at all, it must be exercised by some other nerve than that which is subservient to this purpose in other animals in which it is displayed in the greatest perfection, as they have no nerve corresponding with the olfactory, nor do they present any structure expressly adapted to the exercise of this function.

Birds are universally furnished with the instrument of smell, though they present great diversities in the development of the organs, and appear to be very differently influenced by the sensations it communicates. In general, it is more completely developed in rapacious and fishing birds than in any others. Those birds that prefer putrid animal remains and other garbage, are generally, and perhaps justly, supposed to possess this sense in an eminent degree. Vultures especially have been imagined to be guided to their prey at immense distances, by their scent: that the acuteness of their smell, however, has been much exaggerated, seems to be fully proved by a number of facts. The celebrated Audubon, in his splendid work the Ornithological Biography, has the following observations and experiments respecting the turkey buzzard of America:—

"As soon as, like me, you shall have seen the turkey buzzard follow, with arduous closeness of investigation, the skirts of the forests, the meanders of creeks and rivers, sweeping over the whole of extensive plains, glancing his quick eye in all directions, with as much intentness as ever did the noblest of falcons, to discover where below him lies the suitable prey; when, like me, you have repeatedly seen that bird pass over objects calculated to glut his voracious appetite unnoticed, because unseen; and when you have also observed the greedy vulture, propelled by hunger, if not famine, moving like the wind suddenly round his course as the carrion attracts his eye; then will you abandon the deeply-rooted notion, that this bird possesses the faculty of discovering, by his sense of smell, his prey at an immense distance.

"This power of smelling so acutely I adopted as a fact from my youth. I had read of this when a child; and many of the theorists to whom I subsequently spoke of it, repeated the same with enthusiasm, the more particularly as they considered it as an extraordinary gift of nature. But I had already observed, that nature, although wonderfully bountiful, had not granted more to any one individual than was necessary, and that no one was possessed of any two of the senses in a very high state of perfection; that if it had a good scent, it needed not so much acuteness of sight, and *vice versa*. When I visited the southern states, and had lived, as it were, amongst these vultures for several years, and discovered, thousands of times, that they did not smell me when I approached them, covered by a tree, until within a few feet; and that when so near, or at a greater distance, I shewed myself to them, they instantly flew away much frightened, the idea evaporated, and I assiduously engaged in a series of experiments, to prove, to *myself* at least, how far this acuteness of smell existed, if it existed at all."

His first experiment was as follows:—"I procured the skin of our common deer, entire to the hoofs, and stuffed it carefully with dried grass, until filled rather above the natural size,—suffered the whole to become perfectly dry, and as hard as leather,—took it to the middle of a large open field,—laid it down on its back, with the legs up and apart, as if the animal was dead and putrid. I then retired about a hundred yards, and on the lapse of some minutes, a vulture, coursing round the field tolerably high, espied the skin, sailed directly towards it, and alighted within a few yards of it. I ran immediately, covered by a large tree, until within about forty yards, and from that place could spy the bird with ease. He approached the skin, looked at it with apparent suspicion, jumped on it, raised his tail, and voided freely (as you well know all birds of prey in a wild state generally do before feeding),—then approaching the eyes, that were here solid globes of hard, dried, and painted clay, attacked first the one and then the other, with, however, no farther advantage than disarranging them. This part was abandoned; the bird walked to the other extremity of the pretended animal, and there, with much exertion, tore the stitches apart, until much fodder and hay was pulled out; but no flesh could the bird find or smell; he was intent on discovering some where none existed; and after reiterated efforts, all useless, he took flight, and coursed about the field, when suddenly wheeling round and alighting, I saw him kill a small garter snake, and swallow it in an instant. The vulture rose again, sailed about, and passed several times quite low over the stuffed deer-skin as if loath to abandon so good-looking a prey.

"Judge of my feelings when I plainly saw that the vulture, which could not discover, through its *extraordinary* sense of smell, that no flesh, either fresh or putrid, existed about the skin, could at a glance see a snake, scarcely as thick as a man's finger, alive, and destitute of odour, hundreds of yards distant. I concluded that, at all events, his ocular powers were much better than his sense of smell."

In another experiment he directed the carcass of a hog to be put into a deep ravine, and completely covered over with cane, so as effectually to exclude it from the eye, when he saw from time to time many vultures, in search of food, sail over the ravine in all directions, but none discovered the carcass, although several dogs had visited it, and fed plentifully upon it. This took place in the hottest season of the year, and the smell from the putrid body was so insufferable, that it could not be approached within thirty yards.

Audubon performed several experiments with similar results, and fully satisfied himself that the turkey buzzard is guided to his prey by sight, and not by smell.

In support of similar views, it may be mentioned, that in Greenland, when a whale is captured, although at the moment of capture scarcely a bird may be visible, yet before the operation of flencing has been well commenced, dozens of fulmars and different species of gulls are perceived hastening to the scene from every point of the compass, from the windward as well as from the leeward. In such cases it is impossible to conceive that odorous emanation can extend in opposition to the direction of the wind, even for a few feet. Still, notwithstanding a brisk breeze blowing at the time, birds are seen flying in as great numbers from the windward as from other directions. At the same time, it cannot be disputed that the fulmar and gull tribe, and especially the former, have the apparatus of smell highly developed, and therefore the fair inference is, that they enjoy the faculty in a corresponding degree, and that it is most probably highly useful to them in guiding them to food, placed within the range of its action, though sight be better calculated to detect it at great distances.

That excellent naturalist, my friend, Macgillivray, in the first volume of his History of British Birds, has the following remarks on the raven :—" It has seemed to me strange that in a country where, under ordinary circumstances, few ravens are seen, so many as from twenty to two hundred or more should collect in a few days. In perambulating these islands" (Outer Hebrides) " one scarcely meets with more than a pair in the space of a mile or so; and in Harris, where their breeding-places were pretty generally known to me, I could not count a dozen pairs along a coast-line of as many miles. In Pabbay, as mentioned above, several hundreds had come together, so that the people naturally marvelled whence they had arrived. If, along a coast-line of ten miles, there are ten pairs of ravens, with five young birds to each, or seventy in all, on one of a hundred and forty, there might be nearly a thousand. Pabbay is two miles distant from Berneray, and six from Harris. Even should the wind blow in the latter direction, it is not likely that a raven should smell carrion six miles distant, and in Berneray, which the effluvia might reach, there are not usually more than three or four resident pairs. The birds of the west coast of Lewis, South Uist, and Barra, could not be guided a distance of fifty miles or more by the smell. How then did they arrive in Pabbay? It seems to me that the phenomenon may be explained thus:—

"The two pairs of ravens residing in Pabbay itself would, with their broods, first perceive the carcasses. Those of Berneray might stroll over, as they often do, or they might see the prey, as might those on the Harris coast. Ravens have character in their flight, as men have in their walk. A poet sauntering by a river, a conchologist or fishwoman looking for shells along the shore, a sportsman searching the fields, a footman going on a message, a lady running home from a shower, or a gentleman retreating from a mad bull, move each in a different manner, suiting the action to the occasion. Ravens do the same, as well as other birds; and so, those at the next station, perhaps a mile distant, judging by the flight of their neighbours that they had a prize in view, might natnrally follow. In this manner the intelligence might be communicated over a large extent of country, and in a single day a great number might assemble. We know from observation that ravens can perceive an object at a great distance, but that they can smell food a quarter of a mile off we have no proof whatever; and as we can account for the phenomenon by their sight, it is unnecessary to have recourse to their other faculties."

In reptiles the olfactory organs are not much developed. In the turtle the pituitary membrane is of a very dark colour; the nerve is of considerable size, and its fibres easily traced. In frogs the nostrils are little more than two holes. They are more elongated in serpents, and still more so in lizards, particularly in the crocodile. In none of this class are there any cavities corresponding to the sinuses, so that the air accumulated in the nostrils must be comparatively trifling.

Some physiologists are inclined to limit the sense of smell to such animals as respire air, and therefore deny its existence in fishes, considering the corresponding organs as instruments of taste and not of smell. They do not pretend to deny that the inhabitants of the waters are capable of perceiving very minute differences in the condition of the water, from the presence of foreign bodies, such as dead carcasses, baits impregnated with odorous principles, and so forth; but in all these cases they hold that they are enabled to detect the existence of these substances in water by taste. There is, however, so much analogy between the two senses, that this appears rather to be a dispute about words than about facts. Moreover, it is quite impossible to arrive at any exact determination on a point of this kind, since we can only imagine what perception any animal obtains by the exercise of its organs from the sensations excited in ourselves, and by observing the effects produced by similar objects on the same organs in other animals. Fishes are furnished with organs analogous to those of smell in the higher classes of animals, though the cavities have no communication with the mouth or gullet. They are insulated cavities, having valvular lids over their apertures. The lining membrane is beautifully plaited, presenting an appearance that has a striking resemblance to the under surface of several mushrooms, by which the surface is greatly extended: it is abundantly covered with a viscid mucus. The nerves proceed from the anterior ganglions of the brain. In the cod fish they traverse in their course a large cavity, more capacious than that in which the brain itself is contained. This cavity is filled with transparent fluid, and divided by a central partition. As the nerve proceeds forwards it gradually becomes enlarged, and upon the internal surface of the mucous membrane swells into a ganglion, from which numerous soft filaments penetrate the membrane, apparently to be dissolved, or incorporated as it were, in the mucus. That the cod is guided by smell in the selection of food must be well known to every one who has taken it with bait in circumstances where he could watch the conduct of the fish. If not very hungry, it may frequently be observed to approach the bait, apparently attracted by the sight, till, at a closer distance, it seems distinctly to smell at it, and if not satisfied, turns aside and neglects it.

It appears sufficiently established by numerous facts that many insects are able to distinguish odorous principles even at considerable distances. By this sense the common flesh fly is guided to putrid meat, on which she deposits her eggs. In some instances her instinct is deceived by the smell of a species of mushroom, which gives off an odour exactly the same as that of putrid flesh. In such a situation, however, the eggs, if hatched at all, must produce maggots that immediately perish for want of proper food. The organs by which insects exercise this sense have not been satisfactorily ascertained.

In order that a substance produce an impression on the olfactory organs of animals which breathe air, it is necessary that it be dissolved or suspended in the air; or, more correctly speaking, it is requisite that the matter should be in the gaseous form when presented to the pituitary surface. Some vapours or gases, however, produce no impression on the olfactory nerve, and are therefore termed inodorous, such as the vapour of water; others rouse the common sensibility of the nose, without affecting its special sensibility, such as spirits of hartshorn.

Odours are nearly as various as the principles on which they depend; consequently all attempts to classify them have completely failed. The division into agreeable and disagreeable is quite inadequate, and its unsatisfactory nature sufficiently obvious. It can be applicable only to one species of animals, and even different individuals of the same species are very differently affected by the same substance; nay, the same individual often receives gratification from the smell of a substance at one time, which at another was wont to excite disgust; so much depends on constitution, habit, the state of health, and various other circumstances that cannot be adequately estimated or accounted for. The number of odours being so various, it is impossible to designate them otherwise than by comparing them with others that are common and well-known. Thus we say the vapour of metallic arsenic has the odour of garlic or an alliaceous smell: in like manner we speak of the violet, rosaceous, musky odours, and so forth. The celebrated Linnæus, who seems to have had some superstitious reverence for the number seven, arrays odours into the seven following classes:—1*st*, *ambrosiac*, in which he places the rose and musk; 2*d*, *fragrant*, as the lily, saffron, jasmine; 3*d*, *aromatic*, such as the laurel, and various spices; 4*th*, *alliaceous*, as that of garlic; 5*th*, *fetid*, as in the valerian, and different species of fungi; 6*th*, *virous* or *narcotic*, as in opium, henbane, &c.; 7*th*, *nauseous*, as that of melons, cucumbers, and different species of the gourd tribe.

Odours differ very much as to the permanence of the impression they produce. In some the scent remains even for hours after the application of the substance, while others are exceedingly transient in their effect. They differ also in the extent to which their influence extends, or in their diffusiveness; the effluvia of some being very limited, while others extend to vast distances. It has been stated, that the smell of cinnamon has been wafted on a gentle breeze, so as to be perceptible twenty-five miles from the shores of Ceylon. Lord Valentia mentions, that he distinctly smelt it at the distance of nine leagues. The quantity of matter capable of exciting the sensation of smell, even in the human subject, is inconceivably minute. Scales on which a few grains of musk have been weighed, have been known to retain the odour of that substance for upwards of twenty years. The distinguished physiologist and excellent mathematician, Haller, kept some papers for more than forty years, which had been perfumed with a single grain of amber; yet at the end of that time they did not appear to have lost any of their odour. He calculated, that in this instance, every inch of their surface had been impregnated by $\frac{1}{2691064000}$th of a grain of amber, and that they had scented a stratum of air, at least a foot in thickness, for 14,600 days. A certain degree of moisture in the atmosphere is favourable to the diffusion of odours. The temperature of the air has also a considerable effect; warmth promoting the conversion of the odorous particles into the state of vapour. Hence the flower-garden is at no time the source of greater enjoyment than in the morning, when the dew is evaporating, or after a warm summer shower. Some flowers, however, give off their scent only at certain times, generally when they are fully expanded, and their parts are in the greatest activity.

Like all the other senses, smell is greatly improved by education. Savages, who are accustomed to pay minute attention to the indications of their external senses, enjoy this faculty in a pre-eminent degree. Humboldt affirms that the Peruvian Indians, in the middle of the night, can distinguish different races by their smell, whether they are European, American, Indian, or Negro. In the case of Mitchell, detailed in last chapter, we have seen that his smell was exceedingly acute, as it is in general in the blind. Sometimes it becomes morbidly sensitive. Thus Cloquet refers to the case of an eminent physician in

Paris who was tormented with megrim, in the paroxysms of which his smell became morbidly acute. On one occasion he was very much annoyed with the smell of copper: on a search being made, the source of his annoyance was found in a small brass pin that had been dropt among the bed-clothes.

TASTE.

The seat of this sense is the general lining of the mouth and upper part of the throat, though the superior surface of the tongue is the part on which sapid bodies more commonly make their impressions. The tongue is chiefly composed of muscular fibres, running in almost every direction, and consequently it is possessed of great versatility of motion, and the capability of being moulded into a great variety of shapes. It is formed of two symmetrical halves, and therefore may be considered as a double organ. A slight groove is observable over its upper surface, dividing it into right and left. From this groove a dense fibrous septum extends perpendicularly, terminating in the bridle on the under surface. The tongue is very abundantly supplied with blood, and its nerves we have seen are derived from three sources. There has been considerable discrepancy of opinion as to which of the three nerves is to be held as the special nerve of taste; the opinion now generally acquiesced in, holds the fifth as the proper nerve of taste, as well as of common sensibility; the ninth as that of voluntary motion; and the eighth as the means whereby the organ is brought into association with the throat, gullet, larynx, and so forth.

Three varieties of papillæ are seen on the tongue, distinguished by their forms. About a dozen comparatively large ones are situated towards the root, and are named from their shape *lenticular*. They belong to the class of mucous follicles, several of which are disseminated over the whole surface of the mouth, as on other mucous membranes, to furnish their viscid secretion. Those at the root of the tongue are, however, larger than usual, and, along with the almonds of the throat, afford the mucus with which the bolus of food becomes besmeared in the act of deglutition. The other two sets of papillæ are instruments of gustation: one set consists of small rounded heads, supported on short stalks; their form having suggested the idea of a mushroom, has obtained for them the name of *fungiform*. The other, the most numerous and minute, impart to the tongue its velvety appearance, and are termed the *conical* or *filiform*. These sensitive papillæ are furnished with numerous blood-vessels, and are capable of becoming erected, thus adapting themselves to the active or passive condition of the sense of taste. That these are the peculiar seat of taste, appears from the application of sapid bodies, for, by the aid of a magnifier, they may be seen to dilate and erect themselves, when a camel's-hair pencil moistened with vinegar, or any other sapid substance, is brought in contact with them.

The tongue is not the only instrument of this sense. The lips, gums, palate, and throat likewise participate. Upon all of those parts the fifth nerve is distributed, becoming the channel for the transmission of the sensation to the brain. None of them, however, are so well adapted for being exercised actively, or for undergoing modification, according to circumstances, as the tongue.

In order that the sense be fully exercised, it is necessary that a due supply of moisture be furnished to the different surfaces. Thus the salivary glands are in some measure requisite to the proper exercise of the function, partly by preserving the parts in a proper condition for their office, and partly by serving as a solvent for the substances which excite the sensation; for it is necessary, in order to affect the nerves, that the substance be in solution, otherwise no impression is produced. Insoluble substances, therefore, are totally insipid. Several substances insoluble in water, or in the saliva, but soluble in alcohol or other fluids, produce an intense sensation in the latter case, while in the former they are quite inert. The numerous salts entering into the composition of the saliva no doubt are efficient agents in many cases in reducing substances to a proper condition for making an impression on the gustatory organs. Thus metals impart a peculiar taste, though they are quite insoluble in simple water. Metals applied to the organs of taste in such a manner as to call forth electric action, powerfully impress them. If a thin plate of one metal be placed under the tongue, and another of a different kind on its upper surface, on bringing the edges of the two in contact at the tip, taste is powerfully excited. On touching the surface of the tongue with the point of a wire connected with the positive pole of an electric instrument, a sour taste is experienced, while the negative pole excites an alkaline taste. It does not follow from these experiments that electricity has in itself any savour, but the phenomenon probably arises from electricity disengaging an acid in the one instance, and an alkali in the other, either of which may readily be derived from the saliva. Or the impression from electricity may depend on the electric excitement calling forth the special sensibility of the gustatory organs, in the same manner as this agent rouses the special sensibility of the other senses. Although solution be a necessary condition, so that bodies may impress this sense, yet all liquids are not sapid, nor is savour in proportion to the solubility of different substances: pure water, for instance, has no taste, and gum-arabic, isinglass, &c., though abundantly soluble, have very little.

Savours, like odours, are innumerable, and so various that they do not admit of distinct and satisfactory classification; though we readily comprehend the terms *sweet*, *bitter*, *sour*, *acrid*, *saline*, &c., yet each of these differs in intensity, as well as other shades of character, according to the nature of the material which produces it; and with respect to an infinite number of other savours, we can only convey an idea of them by referring to the individual substance which they may characterize. They vary also according to the permanence or transientness of their impression; some being merely momentary, while others remain fixed as it were for hours. The more permanent savours are sometimes advantageously employed to forestall the sense of taste before the exhibition of nauseous drugs. For this purpose, aromatics and bitters are well adapted. This is further exemplified in the experiment where a person blindfolded has given to him in rapid succession brandy, rum, gin, or different kinds of wines. After a few contacts, all distinction becomes impossible, even by the most experienced. It is necessary that time be afforded for allowing the impression to be made. Accordingly, tasters of wine, tea, and so forth, take a small portion, and move it over the whole surface of the mouth, so as to extend the sphere of its action; while medicinal draughts are generally gulped over as speedily as possible. Different parts of the mouth possess different degrees of susceptibility for sapid bodies; some producing their impression chiefly on the tip, sides, or base of the tongue; others on the lips, gums, or palate; while others again impress principally the throat. Strong savours impair the sensibility to others that are feeble, in the same way that a strong light impairs vision, and a loud noise audition. In like manner, the handling of hard and rough substances diminishes the sense of touch for judging of soft and delicate fabrics, and strong and pungent odours deaden the olfactory organs.

No sense is more influenced by habit than taste. Many substances that are exceedingly disgusting at first, become not only less so, but even highly grateful by custom. Fashion or necessity may at first be the cause of their being taken, but habit soon renders them eagerly sought after. Of this we have innumerable instances in every state of society, in every country, and in all ages, such being known by the designation of acquired tastes.

Thus the most celebrated sauce of antiquity was prepared from the half-putrid intestines of fish. Assafœtida is a favourite condiment with some orientals, and a rotten egg, especially if it contains a chick, is highly esteemed by the Siamese. Fish in an advanced state of decomposition is relished in the northern and western islands of Scotland, under the name of sour-fish. Dried putrid mutton is habitually eaten in Iceland and Faroe; and, in like manner, fully to enjoy high-seasoned game and venison, adapted to the palate of the epicure, some degree of education is necessary. Numerous other examples of acquired taste might be cited that are sufficiently well known, such as a relish for olives, garlic, parmesan cheese, and so forth.

The susceptibility of the organs of taste to pleasurable sensations depends very much on the state of the stomach, even in health. With whatever *gout* we enjoy a favourite dish when we at first sit down with a good appetite, as hunger becomes appeased the relish is diminished, succeeded by satiety; and if, notwithstanding, eating be persisted in, nausea and disgust at length supervene, and the glutton is compelled to desist. This consent subsisting between the stomach and the organ of taste is an important and wise provision, informing the animal when a sufficiency of food has been taken.

In general, those articles that are agreeable to the sense of taste are safe and nutritious; but this is not invariably the case; for one of the most deadly poisons known, the prussic acid, has both an agreeable odour and savour, on account of which it is occasionally used to impart flavour to dishes and liqueurs, such as noyau. Though they are thus rendered fascinating, they are not without danger. Many substances which are at first highly acceptable to taste become after some time, and particularly if too freely indulged, disagreeable. On this principle the grocer acts with a new apprentice, allowing him unrestricted indulgence of his appetite for sweets, till the appetite becomes cloyed, and all temptation disappears: on the other hand, some substances become highly grateful by use, that at first are disagreeable to the palate. This is remarkably the case with bitters, aromatic spices, and pungent stimulants.

The alteration which the constitution undergoes in the progress of age produces striking changes in respect to the relish for various articles of food and drink. Such changes are still more remarkable as resulting from different states of health, a morbid condition of this sense being a frequent concomitant of disease. In jaundice every thing appears bitter; in other affections taste is variously vitiated; while in many conditions it is altogether abolished. Frequently these symptoms depend on the state of the stomach—thus, the presence of acrid matter gives rise to false appetite—but in other cases this may depend on derangement of other functions, or on a peculiar state of the constitution at the time. Taste frequently becomes remarkably depraved, so that chalk, brick-dust, cinders, and the like, are greedily sought after. We have frequently a forcible instance of this in the pregnant female, where the most out-of-the-way articles are ardently longed for, though there is no reason to believe that it ever extends in reality to articles of jewellery or dress, as has been alleged. The most urgent desire is often experienced in such cases for substances which were perhaps previously repugnant to the individual; and it is apt likewise to occur capriciously at the most unseasonable hours, as in the middle of the night.

The lower animals sometimes evince a similar appetite in similar conditions. The settlers in some parts of New South Wales have sustained serious losses from a propensity shewn by breeding ewes for licking earth impregnated with saline matter. A few extracts from Mr Bennett's Wanderings in New South Wales, &c. will afford evidence of this. He says, "On account of the morbid appetite existing in the sheep, which I am about to relate, their natural innocent dispositions are changed;

they become carnivorous and savage; and it is difficult to drive them away from the pits in which the earth impregnated with the alkaline salts may be situated; although, when taken to a *fresh run*, they proceed feeding as usual, until this salt earth is again discovered, when they become addicted to the unnatural custom of devouring their lambs. On discovering one of the pits, they rush to it with activity, licking and gnawing the earth with avidity."

"Among the breeding ewes, eating earth was followed by their devouring the progeny of the other ewes when brought forth; and on the shepherds endeavouring to save from their voracity the lambs just born, they would rush upon them, biting their trousers, and making strenuous efforts to seize the lambs in the arms of the men."—"After eating the earth, they do not feed on the herbage in any regular manner; they are restless, picking a bit of grass here and there, according to the statement of the shepherds, until, on approach of evening, they feed in a more regular manner."

In a letter addressed to government on this subject by a Mr Dutton, and quoted by Mr Bennett, the destructive effects produced among the flocks are clearly pointed out. He says, "The disadvantages which I have thus to detail to you arise from the novel disease with which the sheep are affected. It appeared after the first lambing, and within four months from the time of my occupation of the land in question. Its unaccountable and destructive nature renders my selection utterly useless. The nature of the disease, as far as I have yet remarked, is as follows:—The sheep, in the first place, devour the earth ravenously, the pasture being at the same time luxuriant, principally rib-grass, and other succulent herbs; they become speedily emaciated from this unnatural diet, more particularly as the lambing season advances; and when lambing commences, the other ewes surround the one lambing, and devour the young as they emerge from the mother. The lambs saved through the care of the shepherds become poverty-stricken, from the low condition of the mothers, and generally die before they become a month old. Thus, instead of having twelve hundred lambs this season, as my regular increase, I do not count four hundred; besides a very great decrease from mortality in the maiden sheep, originally purchased at high prices; the number of shepherds required being at the same time twice beyond the proportion usual in the colony."

Mr Bennett observes, "Although the breeding ewes suffer both in health and acquire the morbid appetite of devouring the progeny of others, yet rams, wedders, and ewes not breeding, fatten to an extraordinary degree upon the same pasturage where breeding ewes had become miserably lean, and died in numbers, from being in so low a condition. On one of these spots I saw a wedder killed from a flock, which was so fat as to render the meat almost uneatable; and Mr Manton, who, from the cause before mentioned, had been obliged to remove all his breeding ewes from his pastures about Morrumbidgee, would, nevertheless, send his rams and wedders on the luxuriant pasturage, as the best place to fatten them."

From what has been stated, it will be seen that the sense of taste is not confined to the tongue in the human subject: we are therefore not entitled to infer, because in some of the lower animals the tongue is presented only in a rudimentary state, and in others, from its being of dense texture, or covered with prickles or scales, that they are consequently destitute of this sense. Even in man there have been instances of individuals born without a tongue possessing the faculty, or of others in whom the tongue has been lost, and the sensation remained exercised by other parts of the mouth. Blumenbach says, "I have seen an adult, and, in other respects, well-formed man, who was born without a tongue. He could distinguish, nevertheless, very easily the tastes of salts, sugar, and aloes, rubbed on his palate, and would express the taste of each in writing."

None of the lower animals possess a tongue exactly like that of man. Even in apes, that approach nearest in their organization, it is comparatively much elongated. In ruminants, the tongue is covered with a dense cuticle, studded over with numerous pointed papillæ, especially towards the root. From the direction of these papillæ backwards, and from the waving ridges on their palates, they must derive considerable advantage in collecting and swallowing the tender and succulent herbage on which they feed. In the cat tribe, the sharp horny prickles situated on the tongue must enable them to take a firm hold. In the lion and tiger, these prickles are sufficient to tear off the skin even of large animals. Ant-eaters are furnished with a very long and exceedingly slender tongue, covered with a viscid adhesive secretion, whereby they are enabled to seize on their prey, on thrusting it into the ant-hill. Those whales which obtain their food by filtering water containing it through the plates of the peculiar substance termed *whalebone*, have an enormous tongue, though it may be doubted whether it be endowed with the sense of taste, as these animals receive indiscriminately all substances which are large enough to pass between the plates. Their mode of feeding is curious, and conducted in the following manner: The arctic seas abound with several species of small medusæ or sea-blubber: so crowded are they, that when the water is still, the surface smooth, and particularly when seen between the observer and a large ice-berg deep in the water, they present a striking resemblance to a thick snowfall, when the flakes are large and the air is calm. This is the principal food of the common Greenland whale. That huge animal has projecting downwards from the upper jaw, a kind of palisade, formed of several hundred plates of whalebone, the outer edges of which are sharp, the inner fringed with long hair-like appendages, the spaces between the plates being little more than half an inch. The length of the plates sometimes exceeds twelve feet, where the mouth opens widest—that is, about the middle. This palisade, when the mouth is closed, is covered by the enormous fleshy lower-lip, but when open, it presents a kind of grating, through which the water, loaded with medusæ and other small animals, flows. The mouth is furnished with an immense mass of soft spongy texture constituting the tongue, to all appearance better adapted for licking the food from the hairy whalebone roof, and transferring it to the gullet, than to serve as an instrument of taste.

In many birds, from the horny consistence of the tongue, it cannot well be imagined to serve the purposes of taste. In the toucan, it is several inches in length, and extremely narrow, like a long stripe of whalebone. Fixed to the tip of the tongue of the woodpecker, there is a long sharp-pointed spear-like body with serrated edges, for piercing and seizing on insects burrowing beneath the bark of trees. On the other hand, several animals of this class have soft fleshy tongues, well adapted to the exercise of taste, as in the parrot tribe.

Among reptiles, the tongue presents a great variety of forms and applications. In the crocodile it is so small and immoveable as to have led some naturalists to deny its existence. In the serpent tribe it is forked, and possessed of considerable mobility. In the frog it is folded back in the state of inactivity; but when the animal is about to seize an insect, it suddenly unfolds and projects it out of the mouth. The tongue of the cameleon is contained within a sheath, admits of being projected forth to the extent of six inches, and is besmeared with glutinous secretion. In the twinkling of an eye it is darted out to catch its food, which chiefly consists of flies.

Fishes have the tongue merely in the rudimentary state, and generally fixed near the throat. It is often furnished with teeth. Whether it is subservient or not to taste admits of doubt, as there are no means of determining the fact. Other parts of the mouth, however, may act in this way, as the soft and irritable body on the palate of the carp.

That many of the invertebrated animals are endowed with taste, we have every reason to believe; such as bees, wasps, flies, and leeches. The organs subservient to this purpose, however, have not as yet been satisfactorily ascertained. The condition in which substances most readily act upon the sense (if indeed it be not absolutely essential) is the state of solution. Of the three conditions of matter, then, touch judges most correctly of solids, taste appreciates fluids, and smell takes cognisance of gaseous bodies. In order to excite smell, it is necessary that the odorous particles be inhaled with the breath, and drawn with it through the nostrils, where they come in contact with the immediate seat of the sense. With respect to savours, it is requisite that they be dissolved and brought in contact with the papillæ, in which twigs of the gustatory nerves are incorporated, on which the impressions are made, subquently to be transmitted to the seat of perception.

The intimate connexion subsisting between smell and taste is sufficiently demonstrated in the closure of the nostrils, when the latter becomes much blunted, and almost abolished; wherefore it is nearly impossible to distinguish between the tastes of different substances, as between sweet and bitter, sour and alkaline, and so forth, a circumstance that is occasionally taken advantage of when nauseous medicines are to be administered, by shutting the mouth when the draught is swallowed.

It has been already observed, that neither smell nor taste rank high as channels of intellectual information, although by cultivation their powers are much extended, and their accuracy vastly improved. Dr Kitchener asserts that some epicures are actually able to tell from what precise reach of the Thames a salmon had been caught, when presented at table. But such refinement in either of these senses may truly be held as by no means desirable, since they are liable to so many causes that excite in them offence and annoyance, rather than gratification and satisfaction. Yet in many of the lower animals they are no doubt of the most essential importance in enabling them to select that kind of food that is proper for them, and in rejecting such as might prove prejudicial.

CHAPTER XII.

MOTION.

Organs of Motion consist of the Passive and the Active—Bones—Their Textures and various Forms—Their Chemical Constitution—Adaptation to the purposes they subserve—Variety of Connexion—Gristle—Its peculiar Organisation—Its great Elasticity—Forms the Principal Springs of the Animal Machine—Subservient to Mechanical Movements—Elastic Cushions—Ligament—Its Structure—A very Common Tissue in Animal Bodies—Presents great varieties, and subservient to many purposes—Elastic Ligamentous Tissue a substitute for Muscular Power—Continues its Action in the Dead Body—Tendon—Varieties in the Form of—Bears concentrated Muscular Force—Transfers Muscular Power—Muscular Fibre—Characteristic Property Vital—Organisation—Chemical Constitution—Muscular Action—Changes in the State of Action and Repose—Exciting causes of Muscular Action—The Will—Instinct and Sympathy—Involuntary Muscular Motion—Influence of Disease—Mechanical and Chemical Excitants—Remarkable Effects of Galvanism on the Body of an Executed Criminal—Various Modifications of the Actions of Muscles in the Preservation of the Attitudes, and in Performance of Motion—Force of Muscles—How modified—Muscular Vigour in Different Races—Duration of Action—Velocity of Motion—In Man—In Animals—Mutual adaptation of Structure and Function in Animal Bodies.

In the last four chapters we have had under consideration the instruments by which we become acquainted with the external world around us. We have now to inquire into the mechanical means whereby we are enabled to react on surrounding objects, to change our positions, to fix our attitudes, and to exercise several of those functions to which our attention has already been directed. For these purposes the higher classes of animals are furnished with several distinct organs, of various textures and adaptations, differing in their forms, number, proportion and structures, according to the rank and circumstances of the animal.

The organs subservient to the form, motions, stability, and postures of the body, consist of two classes, the passive and the active. To the former belong the *bones*, *cartilages*, *ligaments*, and *tendons;* the latter comprises the muscular fibre. A few general observations respecting each of these tissues will be necessary.

Bone.—The bones constitute the hardest and most solid parts of the whole system, and are the principal parts that give it form, stability, and posture, forming, as it were, the frame-work of the animal machine. In man and the higher order of animals, the skeleton, generally speaking, is internal; while in the lower tribes, as insects and crustacea, such as the lobster, crab and others, it is placed externally. Including the teeth, the number in the human adult amounts to about 245. They are usually arranged in three classes, the long or cylindrical, such as the bones of the arms and legs, the broad flat bones, as the shoulder-blade, and the round or angular bones, as those of the wrist and ankle. When the broken surface of a bone is examined under a good microscope, it presents an uniform surface, abundantly supplied with minute blood-vessels, without any appearance of fibres or plates. The different densities which bones present, arise from differences in the mechanical arrangement of the particles composing them. In the thigh-bone, for example, the extremities bulge out so as to afford a more extensive surface for the insertion of muscles and ligaments, and to increase their levers by throwing them further from the centre of motion. In the shaft, where strength is chiefly required, the surface is compact, either surrounding a spongy, cellular, or cancellated structure, or forming a hollow tube filled with marrow, thus in the most perfect manner combining the greatest degree of strength with the least degree of weight and expense of material. It can be mathematically demonstrated that the resistance of a cylindrical body, such as a pillar or mast, to a force applied transversely, is increased in proportion to its diameter. The same quantity of matter, therefore, placed in the circumference of a circle, produces a stronger bone than if united in the centre with proportionally diminished diameter.

The broad bones either offer an extensive surface of defence, as in those of the skull, or afford an extended surface for the origin and insertion of muscles, as the shoulder blade. The rounded bones composing the spinal column, and the angular bones of the wrist and ankle, have the osseous matter extended over a considerable space, in order in the most efficient manner to combine the properties of lightness and strength.

The bones are covered with sheathings of dense membrane, with which they are closely united by means of an infinite number of minute blood-vessels. Other blood-vessels enter by appropriate holes in the shafts of the long bones, while a considerable number enter at their extremities. They are thus plentifully supplied with blood. Though many of the vessels are too minute to admit of the free passage of the red particles, yet they readily transmit the colouring matter of madder. Accordingly, when animals are supplied with food mixed with that substance, in a few days the bones are rendered red, or of a pinkish colour, and on the discontinuance of it, in a short time their natural colour is restored, shewing the rapidity with which deposition and absorption is carried on even in the healthy state. Of this we have numerous proofs afforded by accident and disease. How soon, for instance, in healthy vigorous persons are the fractured ends of a bone again firmly united.

In the lattice work of the spongy bones, and the canals of those of a cylindrical form, there is everywhere distributed a delicate membranous web, in the cells of which a modification of fat is secreted, well known under the name of *marrow*. The purpose it serves, or whether it be of any particular use further than as a reservoir of nourishment, has not been satisfactorily ascertained. It is found in greater quantity in the adult and aged than in the young; in the latter, indeed, its place is occupied by a gelatinous fluid.

It is impossible, consistently with our limits and objects, to advert to the infinite varieties of form, texture, and densities that bones present, not only in different animals, but in the same species, in different ages, sexes, and circumstances both of health and disease, all of which exert a powerful influence on the form and development of this part of the animal structure.

Chemical examination shews that bone consists of earthy and animal matter, though chemists are not altogether agreed as to the proportions of the materials, or whether some of the products afforded are or are not to be held as resulting from the processes to which they are subjected. According to Berzelius, in 100 parts from the thigh-bone of an adult, the following is the result of analysis:—

Gelatin	32.17
Blood-vessels	1.13
Phosphate of lime	51.04
Carbonate of lime	11.30
Fluate of lime	2.00
Phosphate of magnesia	1.16
Muriate of soda and water	1.20
	100.00

From the above it appears that about a third part of the substance consists of animal, the remainder being earthy matter. The most minute particle of bone that can be examined yields a portion of animal and earthy substance. Both may be held, therefore, as essential to its composition, and existing in a state of chemical union, and not as a mere mechanical mixture. By subjecting bones to chemical processes, we are enabled to separate the respective constituents from each other. Thus, when immersed for some time in water acidulated with nitric, acetic, and especially with muriatic acids, though they retain their size and form, their weight is considerably diminished, and they are rendered soft, pliable, and elastic. Again, if subjected to strong white heat, as in a charcoal fire, and afterwards allowed gradually to cool, they appear to have undergone no alteration in figure or bulk, but they are rendered white as chalk; their weight is lessened, and they become extremely brittle. By the former process, the earthy matter is removed through the agency of the acid, leaving the animal matter unaltered; by the latter, the animal matter is dissipated by the heat, and the earthy substance alone remains.

The gelatin appears to be in a peculiar state of modification; for although the bones of young animals afford a portion of that substance, still it is only in an inconsiderable quantity. That it exists, however, is proved from their yielding it by long boiling in water, especially in a proper apparatus, as in Pappin's digester, where the heat can be employed considerably above the ordinary boiling point; and thus a portion of nourishment may be abstracted from them. Lately in France biscuits were prepared from bones for the supply of the army of Algiers. Bones are likewise used in the manufacture of glue. The proportion between the animal and earthy substances varies in different individuals, and in the same individual at different periods of life, and under various conditions of health. In youth the former predominates, while in old age the latter is in the greater proportional quantity. Sometimes the earthy matter is so deficient that the bones have not the necessary degree of firmness and rigidity. The consequence is, that those parts of the skeleton which have to support any considerable weight bend under it, as the spine, the bones of the pelvis, and of the lower limbs. Subsequently, on the deposition of the earthy matter, they are rendered sufficiently dense and compact; but the distortion becomes fixed and permanent. On the other hand, a deficiency of animal matter occasionally happens, whereby the proper degree of tenacity is wanting, and they are more readily broken by slight blows or falls.

Among the principal uses of bones are the following:—1*st.* They afford firm pillars of support, in the preservation of the attitudes and relative position, and furnish attachments for the more flexible parts. 2*dly.* They serve as levers and as fixed points of attachment for the muscles by which the various movements are performed; and, 3*dly.* They constitute the chief strength of the cavities for containing the delicate and important organs so essential to the life and well-being of the animal, as the cavities of the skull and spinal canal, for the lodgment and protection of the most important parts of the nervous system; the cavities of the orbits, ears, nostrils, and mouth, for the delicate organs of the senses; those of the chest, abdomen, and pelvis, for the principal organs of circulation, respiration, digestion, &c.

The bones are variously connected with each other by joints or articulations, which admit of different degrees of motion, both in extent and variety. Some of these connexions allow free, easy, and conspicuous motion, as the shoulder and hip joints; others of motion that is rather obscure, as in the instep of the foot; while in others, again, the motion is next to imperceptible, as the bones of the skull and face.

Cartilage is a peculiar animal tissue, well known under the name of gristle, of a pearl colour, and possessing a high degree of elasticity. When cut, it presents an uniform smooth surface, without any perceptible traces of distinct organization, but has an appearance like firm jelly. Neither blood-vessels nor nerves can be traced into the substance of cartilage; not that they do not exist, but they are so minute as altogether to elude the most scrutinizing inspection. Where, however, it comes in contact with the growing extremities of bones, blood-vessels can readily be traced to its margin, and when divided in a living animal with a sharp knife, the smooth surface is speedily bedewed with a serous exudation. In jaundice, too, it becomes tinged with the prevailing colour which characterizes that disease; thus proving the existence of capillary circulation throughout its texture.

Cartilage furnishes a smooth elastic covering to the articular surfaces of bones in the moveable joints. From its smoothness, density, and elasticity, it is admirably adapted for facilitating motion, and diminishing the effects of friction. By immersion for some little time in nitric acid, and then in water, its intimate structure may be unfolded, when it will be seen to consist of an infinite number of minute fibres, arranged perpendicularly, like the pile of velvet. We in this way perceive that in the construction of the joints millions and millions of springs of the most curious and excellent contrivance stand perpendicular to the direction of the force applied, bend to pressure, and on its removal regain their form by their elasticity. When we stand in the erect posture, the number of minute but efficient springs on which the weight of the body rests in the several joints of the back, in the hip, knee, and ankle joints, infinitely surpasses the powers of the human mind to calculate, or even to imagine.

In those parts of the body which require a certain degree of firmness and resistance, combined with flexibility and alteration of figure and posture, cartilage enters into their construction from combining these properties. When treating formerly of the organs of voice, we have had occasion to advert to the manner in which it contributes to the formation of that apparatus. In the construction of the chest, too, cartilage is adopted for fixing the ribs to the breast-bone, and for connecting them with each other; and we have seen that in tranquil breathing muscular power is only required in the act of inspiration, the mechanical conformation of the chest, especially in the presence of the cartilages of the ribs, being sufficient to bring it to the state of expiration to the necessary extent.

A modification of cartilage, termed *fibro-cartilage*, is found in certain joints. It consists of a mixture of ligamentous fibre with cartilage, or rather it is cartilage in a fibrous form, being in this condition better adapted to the peculiar purposes required. In the articulation of the lower jaw, in the joints between the collar and breastbones, at the wrist and knee joints, there are found moveable bodies of this construction interposed between the articular surface of the bones, thus separating them to a certain extent from each other, and thereby rendering the motions more free and extensive. They likewise serve as cushions for the diminution of the jar to which the ends of the bones are exposed. In another modification, somewhat similar to this, we see them interposed between the vertebræ of the back, where the most excellent example of cushions of this kind is presented. The cartilaginous fibres of these intervertebral cushions are intermingled with a liquor of a thick and viscid consistence. This liquor is in the greatest proportion in the centre, the number of the fibres increasing towards the circumference. Thus most admirable cushions are formed for the support of the weight of the body, and for the admission of free and easy movement to the necessary extent.

A combination of ligament and cartilage is interposed between several bones that admit of scarcely perceptible motion, as the collar-bone with the shoulder-blade, and the different bones of the pelvis. Cartilage is also attached to the margins of some of the broad flat bones, in order to increase the extent of their surface.

Like the bones, cartilages receive dense membranous sheathings closely attached by blood-vessels and tough filamentous cords, whereby their strength and tenacity is greatly increased.

Cartilage presents some of the properties of coagulated albumen; the stronger acids dissolve it, such as the nitric, sulphuric, and muriatic; but the weaker, such as vinegar, have little effect, unless it be long macerated in them, when it is rendered soluble in water, and appears to be converted into a kind of jelly. Gelatin may likewise be procured from it by long boiling.

Ligament is one of the toughest and strongest tissues in the animal body. It consists of strong bluish or grey fibres of satiny lustre, intricately interwoven together in various directions, so as not to admit of being unravelled. This tissue enters very extensively into the construction of the body, and presents great diversities in form, arrangement, and texture, according to the purposes to which it is subservient. All the moveable joints are furnished with ligaments. In some, as the shoulder-joint, there is merely a cup-shaped sheath surrounding the articulation, of different degrees of strength, at various points of the circumference, according as it is more or less supported by muscles. This conformation admits of free and extensive movement in every direction. In other joints, where the motions are limited to certain directions, as in the elbow and knee, besides the general capsular investment, there are, in addition, round or flattened bundles of great strength, which not only serve the purpose of binders, but likewise confine the movements to the required directions. The internal surface of the ligamentous capsules, as well as the cartilaginous coverings of the bones, have a delicate expansion of secreting membrane for the supply of the liquor of the joints, termed synovia, which lubricates the surface, and serves the same purpose that oil does in a piece of machinery. Every joint of the body has its ligaments accurately adjusted to its individual mechanism, so that every one of them serves to illustrate the wisdom of design, the excellence of the contrivance, and the beauty of the workmanship in their machinery.

In other parts, ligaments pass from one point of a bone to another, or fill up holes where from their toughness they afford a surface for the attachment of muscles of greater strength and lightness than bone could have furnished. In some situations, again, they form strong bandages, as at the wrist and ankle, and along the fingers and toes, where they bind down muscles or their tendons, and enable them to act with greater steadiness and precision than they could otherwise have done. Were it not for the ligamentous bandages, the tendons would start up from their situations on being pulled by the muscular fibres connected with them. Their power would be thus diminished, and the symmetry of the body greatly impaired. Occasionally they are sprained from over-exertion or accident, when an artificial bandage becomes necessary, in some measure to supply their place, and then is it known how superior they are to any artificial contrivance, however cunningly devised, or however dexterously applied.

The ligamentous tissue is sometimes expanded into broad sheets, under the name of *fasciæ*, or when these expansions are connected with muscles, they are termed *aponeuroses*. They present great varieties in form, strength, and arrangement. They furnish coverings which surround not only the muscles and other structures in the various regions of the body generally, but likewise the individual parts, form partitions between them, and afford linings for the separate portions composing them. In the loins, and along the back there is a strong binder of this kind, which greatly facilitates the motions of the body, and powerfully contributes to the action of the muscles. Where this is weak, a belt round the waist is of considerable service; but in a well-formed person it is a clumsy substitute of art for nature, and ultimately tends to weaken the back, for exercise strengthens and invigorates all parts of the frame, while artificial substitutes invariably weaken the parts they are supposed to strengthen.

The varieties of the ligamentous tissue adverted to are chiefly characterized by their tenacity and intricate interlacement of the threads composing them, toughness and strength being the properties principally required in the office they have to perform.

Allied to ligament in some respects, we have a peculiar tissue, which has been ranked under a distinct order in the classification of the animal textures. It is distinguished by its high degree of elasticity, its fibrous structure, and yellow or tawny colour; hence it has been named the *yellow fibrous* or *elastic tissue*. It is known by the Scotch word *fixfax*. It is by far the most elastic substance in the animal body. This mechanical property fits it for many purposes, and adapts it to several situations where the preservation of certain postures, attitudes, or forms, with the capability of alteration in these respects, is requisite. It is very conspicuous in the neck of those animals which have to support a heavy load horizontally at the extremity of a long neck, as in the elephant, the deer, and our domestic cattle. Had their heads been supported merely by muscular action, as that is liable to fatigue, and requires intervals of rest, as well as the exercise of volition, the postures could not have been sustained for any length of time without pain and exhaustion. This tissue, which is liable to none of these objections, is accordingly substituted for muscular power, in fixing the forms, preserving the attitudes, and contributing to motion. The strong fibrous band, stretching along the back part of the neck to the head of these animals, enables them with perfect ease to support the head. It is also the cause of the head being bent back in dead animals, as its power is entirely *physical*. In virtue of its elasticity, it continues to exert its force after death, when that of the muscles has altogether ceased. It is likewise adapted for retracting and retaining the sharp claws of the cat tribe within their sheaths when not in use. The wings of birds, also, in the state of rest, are retained bent by a ligament of this tissue. Along the bellies of cattle, broad bands of the same structure are extended, in order to support the contents of the abdomen. It is not much employed in the preservation of the attitudes of the human subject, though traces of it are met with along the spinal column, where it contributes to the maintenance of the erect posture. The elasticity observable in tubes, such as the windpipe and its branches, blood-vessels, and certain excretory ducts, is owing to the presence of this particular tissue in their organization.

Ligament appears to be a combination of coagulated albumen and gelatin, under a peculiar modification. In the elastic tissue, traces of fibrin have also been detected. Both structures forcibly resist chemical action and decomposition.

Tendon or Sinew.—This tissue must be well known to every one, constituting, as it does, so common an appendage to muscles. At the wrist, on the back of the hand, at the heel, the sinews or tendinous cords are distinctly perceived in the living body. They have a white satin-like glistening lustre, possess great physical strength, but have little or no elasticity. They are composed of filamentous threads, generally running parallel, but variously interlaced, and bound together by transverse threads. They vary much in their figure and extent, being sometimes cylindrical, tapering to the point of their insertion, and flattened where they spring from the muscular fibres. In some situations they form broad expansions, under the name of aponeuroses. Tendons are to be considered as simply appendages to muscles. They receive merely colourless blood, and in their healthy state are totally insensible, so that the strongest and thickest tendon of the body, that of the heel, known by the name of the tendon of Achilles, may be (and it occasionally is) snapt across, and yet the accident is accompanied with not the slightest degree of pain, the sufferer conceiving, perhaps, that a part of the floor has given way under him, or that he has received a smart stroke from behind. Where the force of a muscle is concentrated, there it becomes tendinous, since tendon, from its insensibility, is capable of bearing such concentration without pain or fatigue. Where it passes over joints, there also it becomes tendinous. So likewise where the force is to be exerted upon some distant part, it is transmitted along a tendon, as forces in machinery are by ropes. In some instances, where tendons cross over joints, a bone is formed where they cross. Of this we have an example in the knee-pan, which is nothing more than a round bullet-shaped bone, formed in the course of a strong tendon, possessing the advantage of throwing the force farther from the centre of motion, thereby increasing the lever, and consequently the effect. Similar bones in the course of tendons are by no means rare in the animal body, particularly in the tendons of the feet.

Muscular Fibre.—This tissue must be familiar to every one, under the name of flesh. Its most characteristic property is essentially vital, consisting in the innate power of contraction, a property which distinguishes it from every other texture in the body. By the aid of the most powerful microscope, it appears to consist of exceedingly minute threads, so fine, according to estimate, as the $\frac{1}{10000}$th part of an inch in diameter. The ultimate filaments are collected together, so as to form a fibre. The fibres are easily perceived in boiled flesh, and the number of ultimate filaments of which each is composed, varies in different muscles, and in the same muscle in different animals. Several fibres are again collected, so as to constitute what is termed a fasciculus or bundle, and according to the size of the bundles, the muscle appears coarse or delicate. Thus a number of ultimate filaments form a fibre; a collection of fibres a bundle; and these bundles collectively constitute a muscle. The fibrous and fascicular arrangement appears to be chiefly confined to muscles of voluntary action, being scarcely perceptible in the heart, and not recognisable in the alimentary canal or urinary bladder. It is very distinct, however, in the stomachs of very many birds, especially in hawks and owls.

The muscular fibres are everywhere penetrated by cellular tissue, and numerous blood-vessels and nerves. According to the quantity and quality of the blood, the colour of the muscles varies. In adult and vigorous animals of the class mammalia, it is of various shades of red; in young animals it approaches to a cream colour, as in veal; in birds it presents great diversities, not only in different species, but in the different muscles of the same individual, sometimes being very dark red, while in others it is whitish; in fishes it is bluish or white, and of various other tints.

The direction of the fibres of muscles varies; in some they lie nearly parallel to each other, when the muscle is said to be straight; in others they radiate in different directions; in others they are disposed obliquely to the general direction of the muscle, giving rise to their classification into penniform and semi-penniform; others again are circular; not that we have in any case a fibre continued round the whole circumference of a circle, but in several instances a series of fibres, forming segments of circles, complete the circumference, as in the intestinal canal and in the muscles called sphincters.

As far as has been ascertained by chemical analysis, muscular fibre consists of fibrin, albumen, osmazome, and gelatin. It is not easy to determine in what particular condition or proportion each of these constituents enter into the constitution of the tissue. It is well known, however, that the proportions they yield vary according to different conditions, as the species of animal, its age, sex, state of health, and so forth. The flesh of young animals, for example, affords a large proportion of gelatin, while it is deficient in fibrin. In the adult animal, the reverse occurs,—fibrin predominates, and gelatin is deficient.

Muscular Action.—Contractility, the characteristic property of muscular fibre, is essentially a vital property, since it can be ascribed neither to chemical nor mechanical laws; its existence in and connexion with the muscular fibre is an ultimate physiological fact, which does not admit of explanation. In this vital property we recognise a *source*, and not a mere *application* of power.

The most evident alteration a muscle undergoes in a state of action is a diminution of length, with a corresponding increase in thickness. Both in the state of relaxation and contraction its actual bulk has been ascertained to remain precisely the same. Very opposite opinions have been and are still entertained with respect to the efficient cause of muscular action. The opinion which appears best to accord with the observed phenomena is that which ascribes it to a change in the form of the constituent fibre, becoming more or less bent in opposite directions, so as to present zig-zag lines, the angles formed being more or less acute, according to the degree of contraction. Fig. 38 represents a series of muscular fibres in a state of relaxation, with a nervous filament ramified through them, as observed under the microscope. Fig. 39 shews the change which takes place in the state of contraction, where, instead of the fibres lying parallel, or nearly so, as in the former instance, they present zig-zag lines.

FIG. 38.

FIG. 39.

Various exciting causes call forth muscular action. The principal stimulants are the vital, the morbid, and the mechanical and chemical. The vital excitants are chiefly displayed through the medium of the nerves, in the voluntary, instinctive, and involuntary movements.

Volition enables us to exert the action of those muscles placed under the control of the will, and, by means of what is termed the muscular sense, we are enabled to apportion the degree of contraction to the effect required.

We do not use the same effort in lifting one grain as we do in raising a hundred-weight. The adaptation of the effort to the effect was strikingly displayed by the elephant Chuny a few years ago at Exeter Change. When filberts were given him, he placed them under his ponderous foot, and cracked the shell without bruising the kernel,—so accurately did he calculate the power to the desired effect. Many muscular movements which have become easy and familiar to us by habit and education, appear to require no intervention of the will, because that power may be transmitted along the nerves as quick as lightning, and as quick as lightning the muscle responds to the call. The first attempts at writing, playing on musical instruments, and several mechanical arts, are awkward and imperfect; but how easy do they become, and with what celerity are they performed, when practice has made them familiar. Walking, running, dancing, and many other motions, require education before they can be executed with facility, quickness, or grace. Powerful effects result from the condition of the mind. Many of the more pleasurable mental feelings, as hope, confidence, and joy, brace the muscles, increase their vigour, and enable them to perform their function with alacrity and ease. Joy displays its influence chiefly on the action of the heart, which may be augmented to such a degree as to induce palpitation. The consequences of this increased action of the heart are the augmentation of the force and velocity of the blood, fuller and more powerful inspirations of air, a rapid circulation towards the surface, an increased brilliancy of the eyes, and an augmentation of the temperature of the body. The more stormy passions, as anger, and particularly when accompanying delirium or madness, produce astonishing effects; the muscular contractions are then performed with immeasurable, and almost uncontrollable force; strong bonds are broken asunder; and a thin, delicate female resists the efforts of several strong men to subdue her during the paroxysm, while after it is spent a child may bind her with a woollen thread. On the contrary, the depressing emotions, such as despondency, sorrow, and fear, paralyse, as it were, the muscular power; the heart fails in propelling the blood in due quantity to the surface; the face becomes blanched, and the limbs tremble.

When treating of the nervous system, we have seen that the nerves from the cerebro-spinal portion of that system, distributed on the muscles, perform separate offices; one set of nervous filaments conveying to the muscle called into action the commands of the will, the other set communicating to the mind the fact that the order has been complied with. The issue of the command, and the announcement of its performance, constitute the chain of effects in purely voluntary muscular action; if one be deficient, then is the result imperfect. Thus, a person paralytic as to feeling, with retention of the power of throwing the muscles into action, may hold in his grasp an object, so long as his attention is fixed upon that act; but the moment the attention is withdrawn, in the same instant the object is dropt. For the performance of purely voluntary motion, more or less education is necessary, according to the complexity of the operation required.

But the muscles which usually obey the will may likewise be called into action without any previously determined purpose, such as involves the exercise of volition; and still we may feel conscious of the muscular action employed. Instinctive and sympathetic movements are of this kind:—the act of sucking in the new-born infant, deglutition of food, winking the eyes from the apprehension of injury, throwing the arms forward when falling, coughing from the irritation of the air-passages, sneezing from the application of pungent substances to the nostrils, and many other motions, which are performed from an irresistible impulse, without the necessity of predetermination or volition, and even in many cases in spite of them. In all these instances, motions are performed as perfectly the first time they are attempted as at any subsequent period, however often they may be repeated; and whatever number of muscles are called into action, they invariably operate with the precise degree of force, velocity, and extent, and in the exact degree of combination and order of succession for the end required, without previous education or training.

Involuntary movements are performed, not only independently of the will, but without our being conscious of them. Of this kind are the motions of the heart, those of the stomach and intestinal canal, the contraction of the urinary bladder,—the blood acting as a stimulus in one case, the aliment in another, and the urine in a third. Various diseased conditions induce muscular action in different degrees of intensity and permanence, giving rise to spasms, such as locked jaw, and convulsions of various kinds. Mechanical and chemical stimulants produce muscular contractions, not only in the living body, but even after death has taken place. The facility with which they may be excited after death depends much upon the state of the body immediately preceding, on the nature of the death, and the interval elapsed from its occurrence. When an animal is killed, and when all motion has ceased, motion may be again excited by mechanical irritation of the nerves supplying the muscles, as by scratching them with a needle, or the heart may be roused to contraction by pinching. But the most remarkable effects result from the application of electricity: this agent is well known as a powerful stimulus to muscular contraction in the living body, and it is by far the most powerful that can be applied in the dead. Dr Ure has given a most remarkable instance of the effects of galvanism upon a human subject which he operated upon a few years ago in Glasgow. It was the body of a murderer of the name of Clydesdale, a powerful middle-sized man about thirty years of age. After being suspended from the gallows about an hour, having had no convulsive struggles when he dropped, he was carried to the anatomical theatre about ten minutes after he was cut down. His face had a perfectly natural appearance, without lividity or swelling; neither had the neck been dislocated.

An incision was immediately made in the nape of the neck, in order to expose the spinal marrow. The principal nerve of the thigh was laid bare on the left hip, and a small cut was also made in the heel: from neither incision did any blood flow. A pointed rod, connected with one end of a powerful galvanic battery, was brought in contact with the spinal marrow, while a similar rod, connected with the other end of the battery, was applied to the nerve at the hip. Every muscle of the body was immediately agitated with convulsive movements, resembling a violent shuddering from cold, the left side being most powerfully affected. On removing the rod from the hip to the heel, the knee being previously bent, the leg was thrown out with such violence as nearly to overturn one of the assistants, who in vain attempted to prevent its extension.

In order to excite the movements of breathing, the nerve of the diaphragm (the principal muscle of respiration) was exposed in the neck, and one of the rods applied to it, while the other was brought in contact with the diaphragm through an incision made under the seventh rib. On the circuit being completed, the diaphragm instantly contracted, but with no great force. "Satisfied," says Dr Ure, "from ample experience on the living body, that more powerful effects can be produced in galvanic excitation by leaving the extreme communicating rods in close contact with the parts to be operated on, while the electric chain or circuit is completed by running the ends of the wires along the top of the plates in the last trough of either pole, the other wire being steadily immersed in the last cell of the opposite pole, I had immediately recourse to this method. The success of it was truly wonderful. Full, nay laborious breathing, instantly commenced. The chest heaved and fell, the belly was protruded, and again collapsed, with the relaxing and retiring diaphragm. The process was continued without interruption as long as I continued the electric discharges.

" In the judgment of many scientific gentlemen who witnessed the scene, this respiratory experiment was perhaps the most striking ever made with a philosophical apparatus. Let it also be remembered, that for full half an hour before this period, the body had been well nigh drained of its blood, and the spinal marrow severely lacerated. No pulsation could be perceived meanwhile at the heart or wrist; but it may be supposed that but for the evacuation of the blood, the essential stimulus of that organ, this phenomenon might also have occurred."

In a third experiment, the nerve of the forehead was exposed, and one of the rods applied to it, the other to the heel. Dr Ure says, " Every muscle of the face was thrown into fearful agitation. Rage, horror, despair, anguish, and ghastly smiles, united their hideous expressions in the murderer's face, surpassing far the wildest representations of a Fuseli or a Kean. At this period several of the spectators were forced to leave the room from terror or sickness, and one gentleman fainted."

The last experiment consisted in transmitting the electricity from the spinal marrow in the neck to one of the principal nerves of the arm at the elbow, when the fingers moved quickly like those of a violin player; and an assistant who tried to close the fist, found that the hand was forcibly opened in spite of every effort to prevent it. When the rod was applied to a slight cut on the tip of the fore-finger, the fist being closed, the finger was instantly extended, and from the convulsive movements of the arm, he seemed to point to different spectators, some of whom thought he had come to life.

Suppose a joint capable of motion in no less than four cardinal directions, and its motions regulated not by four, but by six, eight, ten, or twelve different muscles, all of them capable of varying the force, the extent, duration, and order of succession of these actions, at the pleasure of the will, the variety of effect must be almost incalculable. In the regulation of these motions, a smaller number of muscles than four can never be employed; and even these must be employed in different capacities to produce their effects with steadiness and accuracy. Let us take the motions of the head for example: Suppose we bend the head forward, there must be muscles, not only to carry it forward, but likewise others to prevent its inclination to the right or left; and as the head can also be moved in the opposite direction backwards, there must also be muscles to oppose or antagonize those that bend it forward. The muscles in the direction of which the head is moved are in this case termed *motors*, those that prevent its vacillation to either side *directors*, and those which antagonize them *moderators*.

Further, these motions could scarcely be executed with firmness and precision, unless the muscles producing them have a fixed point of action. Winslow mentions the case of a lady who was incapable of raising her head from the pillow. Various painful applications, such as blisters, &c. were applied without effect to the region of the neck. No treatment produced the slightest beneficial result till a physician, master of the motions of the body, was consulted, when it was ascertained that when she attempted to raise her head, and with this view threw the powerful muscles arising from the breast and collar bones into action, instead of the head being carried forward to the breast, the breast was raised up towards the head. On further examination, it was observed that the ribs and breast-bone were unusually unsteady: this was found to arise from a preternatural laxity in the muscles of the abdomen, by which they are drawn down and fixed. When this condition of matters was ascertained, a bandage was applied round the waist, in order to fix the chest, and afford a fixed point of action to the muscles of the neck employed in bending the head forward. The lady was now desired to rise from the pillow, and to the astonishment of herself and the bystanders, she got up with facility, the simple application of the bandage round the waist having appeared to perform a miraculous cure. Hence it appears that in changing the positions and attitudes, a number of muscles not employed as motors, directors, or moderators, are engaged as *fixors*.

Lastly, as all the motions that vary the positions of the head, trunk, and limbs, must likewise vary the centre of gravity of the body, a number of muscles must be thrown into action for the preservation of the equilibrium, whether a person be sitting, standing, or moving from one place to another. Muscles thus engaged in maintaining the balance are termed *librators*. In general, we are unconscious of their action, unless they happen to be in a state of morbid sensibility, or unless, in performing a motion we did not intend, we happen to stumble, or upon suddenly changing the librators we experience a violent jerk in the whole body; then we are surprised how muscles so distant, and in so great a number, should be concerned in merely changing the position of a part.

It is from the muscles being always ready to act on the shortest notice in every emergency—from their general prompt co-operation in harmonizing the various motions throughout the system—from the yielding, yet steady flexibility of the joints—from the oblique opposition of their surfaces—from the angles, the curves, and the varied direction of the bones united by articulation—and from the elastic substance interposed, that the body is enabled to resist so successfully the violent jars to which it is exposed in running, leaping, in stopping suddenly, or in falling from a height. By such happy contrivances, forces applied to the body are rapidly diffused throughout every part, so that in ordinary cases, even the functions of the most delicate are seldom impeded. To these, more than the strength of the bones, the ligaments, and the muscles, are we frequently indebted, in cases of concussion, for the safety of the contents of the head, chest, and abdomen. This is obvious from the violent jerks to which men in a state of intoxication are exposed, from inability to regulate their equilibrium; from the violent shocks which we often receive in attempting to recover our balance; from distortions of the joints in rheumatism and paralysis; and from the number of dislocations and fractures arising from unequal action in the muscles, when they happen to be taken off their guard.

In order to change and fix the attitudes with steadiness and accuracy, it is necessary that numerous muscles be called into action with various degrees of force, to different degrees of extent, and in various states of combination; and not only this, but it is also necessary that all the various forms of the joints should be mutually accommodated to one another; hence it is that the functions of joints are not only closely and accurately connected, but all the joints so adapted to the muscles, and all the muscles so adapted to the joints, that amidst some millions of possible relations which they might have had, the particular relations which they actually have are the only relations, so far as we can judge, that could have rendered them fit to co-operate; and yet these relations, numerous, and minute, and intricate as they are, are, so far as essential, regularly preserved from birth to maturity; for as the bones grow in size and in strength, so grow the muscles in their fleshy and tendinous fibres; in due measure is the blood transmitted, as to quantity, velocity, and force; with the necessary adjustment are the fibrous and cellular sheaths supplied, and the nervous cords distributed; so that, free from disease, and free from the natural infirmities of age, the voluntary muscles, when properly directed, are capable of performing their functions in all the different periods of life.

We speak of a muscle being in the state of contraction and in the state of relaxation, but it is to be recollected that these are only relative terms: when we say that a muscle is in a state of relaxation, it is still endowed with energy, and only relaxed compared with some one or other of its former conditions, or with the condition of other living muscles, and never in that state of relaxation which a muscle exhibits in the dead body. Although contraction be the most active condition of the muscle, and that which usually gives rise to motion in the healthy and vigorous state of the system, nevertheless motion may also result from the passive state of relaxation, for motion results merely from a subversion of the balance between the antagonist muscles of a part, and may equally arise from the one losing or withholding a certain degree of power, as from the other exerting it. Thus the equilibrium of loaded scales will be destroyed equally whether we withdraw a portion of the weight from the one or add additional weight to the other. For example, let us take the wrist-joint when the hand is stretched out, so that the palm is parallel with the fore-arm; so long as it is kept steadily in this position, the different muscles that tend to bend it forwards and backwards, inwards and outwards, all perfectly balance each other, from their acting with precisely the same degree of force. But suppose the muscles which bend the wrist forward relax in their action, then will it be bent backwards, although the antagonists exert no more force than before. Thus we perceive that relaxation may be the cause of motion as well as contraction, and that it is so is sufficiently well established. When a person becomes drowsy, the eyes are closed, and the head falls forwards, not that the muscle which closes the eye in the one case, or those that bend the head in the other, are in a more active state, but because their antagonists become comparatively relaxed. Numerous motions that occur, especially in a state of debility, in various diseased conditions, and at the approach of death, arise from this cause, that is, from diminished, and not from increased action.

Force of Muscular Action.—The force which a muscle exerts partly depends upon its vital energy, and partly on its physical condition. As the principal power is derived from a vital source, the change produced by death is sudden and obvious. The muscles that when living could have ruptured their tendons, dislocated the bones, and broken them to pieces, when dead become soft and flabby; and were it not that they are held together by their sheaths, cellular membrane, and blood-vessels that every where penetrate them, and for some time hold them together, they would scarcely be able to support their own weight. A muscle composed of large firm fibres will contract more forcibly than one with soft, delicate, loose fibres. Like every part of the body, the muscular power is greatly influenced by the state of health, and the effects of a due degree of exercise is in no part of the animal frame more strikingly displayed. Thus the legs of the pedestrian become strong and vigorous, the arms of the blacksmith are rendered powerful, and the shoulders and loins of the porter are enabled to bear heavy loads with comparative ease. When a muscle is in action, as already observed, it swells and is shortened, the enlargement in diameter corresponding to the diminution in length, so that no change of bulk occurs; at the same time it is rendered harder and firmer according to the degree of energy with which it is endowed. The muscle which shuts the jaw, and which is inserted into its angle, cannot shorten itself beyond a certain extent when the teeth are brought forcibly together, but on placing the points of the fingers upon it when it swells out the cheek, by its action, it will be found to have different degrees of hardness according to the energy of its contraction. In the condition of forcible contraction, muscles become elastic, and are also supposed to be in a state of vibratory oscillation, during which they are capable of resisting sharp and heavy blows with comparative impunity. It is in this way that the common feat of bending a poker across the fore-arm is explained. They likewise become less sensible to punctured and incised wounds. In a surgical operation, therefore, the muscles instinctively start into powerful action to prepare for resistance. When strung to the utmost state of excitement, as in a pugilistic combat or in the field of battle, they bear with impunity blows and wounds that in their state of relaxation would greatly injure them. In some cases of inordinate action the muscles have been known to snap across the powerful tendon of Achilles at the heel, and in other cases to fracture the knee-pan, and even the thigh-bone.

Numerous instances of surprising strength have been recorded. One of the most remarkable and best authenticated is recorded by Sir David Brewster in his Letters on Natural Magic. It is the case of Thomas Topham of London. Dr Desaguliers saw him, with the strength of his fingers, roll up a very thick and large pewter dish. He lifted with his teeth a table six feet long, which had half a hundred weight hanging at the end of it, and held it in a horizontal position for a considerable time, the feet of the table resting against his knees. He broke a rope about two inches in circumference, which was in part wound round a cylinder of four inches in diameter, having fastened the other end of it to straps that went over his shoulders. He lifted a rolling stone 800 lbs. in weight with his hands only, standing in a frame above it, and taking hold of a chain that was fastened to it.

The mean effect of the labour of an active man, working to the greatest possible advantage, and without impediment, is generally estimated to be sufficient to raise ten pounds ten feet in a second, for ten hours in a day, or to raise 100 pounds one foot in a second, or 36,000 feet in a day, or 3,600,000 pounds in a day. Dr Desaguliers affirms that the weakest men who are in health, and not too fat, lift about 125 pounds, and the strongest of ordinary men 400 pounds. Topham, we have observed, lifted 800. The daily work of a horse is estimated to be equal to that of five or six men.

It would appear that civilization is favourable to muscular strength, which has also some relation to the different races of mankind. Péron, in his voyage round the world, took with him one of Regnier's dynamometers, which measures the relative force of men and animals. He directed his attention to the strength of the arms and of the loins, making trials on several individuals of various nations, viz. twelve natives of Van Diemen's Land, seventeen of New Holland, fifty-six of the island of Timor, seventeen Frenchmen belonging to the expedition, and fourteen Englishmen in the colony of New South Wales. The results are stated in the following table. It may be observed that the value of the *kilogramme* is about two pounds avoirdupois, and that of the *myriagramme* about twenty.

	Strength: Of the arms. Kilogrammes.	Strength: Of the loins. Myriagrammes.
1. Van Diemen's Land	50.6	
2. New Holland	50.8	10.2
3. Timor	58.7	11.6
4. French	69.2	15.2
5. English	71.4	16.3

The highest numbers in the first and second divisions were respectively 60 and 62, the lowest in the fifth 63, and the highest 83 for the strength of the arms. In the power of the loins, the highest among the New Hollanders was 13, and the lowest of the English 12.7.

Duration of Muscular Action.—It has been already stated that the terms contraction and relaxation of living muscles are only relative; that a certain degree of contraction always exists, and that the degree of action depends the energy of the exciting cause, though influenced to tain extent by the physical condition of the muscle engaged. Involuntary muscles are remarkable for the very rapid and continued alternations of comparative action and repose; thus, from the first time the heart exercises its function till it ceases to act at the moment of death, it continues incessantly its oscillations of action, though the period between may extend to seventy, eighty, or a hundred years; and that too whether we are asleep or awake, by day and night, in health and disease.

The duration of voluntary motion depends in a great degree on the determination of the will, and the influences with which it may be actuated. In the East, fanatical enthusiasts have been known to persevere in certain postures till they have become actually incapable of altering them. It is impossible to conceive such endurance without a certain degree of enthusiasm to keep it up. This connexion between the condition of the mind and muscular contractility is similar to other extraordinary changes which take place in the system of credulous persons, whose fancies are under the impressions of witchcraft, insanity, or animal magnetism, and accounts also for the few real cures in the annals of modern empiricism that are so ostentatiously blazoned forth when they happen to occur. The same connexion likewise explains how our muscular strength is varied by the states of sickness and health, and how our exertions are more or less vigorous and extensive, continued for a longer or a shorter period, and attended with greater or less fatigue, in proportion as the mind happens to be influenced by the exhilarating or depressing passions.

The continuance of muscular action under the influence of the will, in preserving a particular attitude, in bearing a burden, and so forth, sooner or later induces exhaustion, and the necessity for rest is experienced. But even during the preservation of a fixed posture, the muscles engaged experience certain intermissions or oscillations in the intensity of their contraction, which in some measure accounts for the length of time they may be persevered in.

Velocity of Muscular Action.—The velocity with which the voluntary muscles contract, depends in a great measure on the influence of the will, at the same time that it is regulated to a certain extent by habit, those movements to which we are accustomed being executed with the greatest celerity and ease, while those that practice has not rendered familiar are performed slowly and deliberately. The velocity of movement, as well as the influence of habit, are displayed by performers on musical instruments, as the violin, flute, and piano-forte, in writing, speaking, running, and so forth. The celebrated Haller states that he conld articulate distinctly 1500 letters in the space of a minute; and as the relaxation of a muscle occupies as much time as its contraction, each change in the pronunciation of one of the letters in this instance must have occupied not more than the three thousandth part of a minute; yet this is slow in comparison to the velocity with which changes take place in drawing a straight line with the hand, where the line is composed entirely of points belonging to the circumference of as many circles, and where every point, of which there may be thousands in a second of time, requires an alteration in the condition of the muscles employed. Haller calculates that the *rectus*, one of the principal muscles of the thigh for the extension of the knee, contracts three inches in the twenty-eighth part of a second in the most rapid motions of the leg.

Though the human body affords numerous instances of quickness of motion almost inconceivable, yet the various classes of animals present many examples of velocity far surpassing any thing that occurs in the human subject. *Eclipse*, one of the fleetest race-horses on record, passed over a mile in a minute and a half, and *Childers* ran ninety feet in one second, which is at the rate of upwards of a mile in a minute. Haller has calculated that a race horse, at the height of his speed, must lift his leg in the seventieth part of a second. Still this is far outstripped by what may be observed in birds, many of which are capable of wheeling round and round the most rapid racer in circles of immense diameter. Montagu, the ornithologist, estimates the flight of several of the falcon tribe as equal to 150 miles an hour. A falcon belonging to Henry IV of France made its escape from Fontainbleau, and was caught twenty-four hours after at Malta, a distance of not less than 1350 miles, being at the rate of about fifty-seven miles an hour; but as falcons do not fly by night, nor is it likely that he was caught immediately on landing at Malta, the flight must have been at a much greater velocity. Many other instances are afforded by birds, not merely of quickness of motion, but of long continuance and great power, not only without fatigue, but apparently with the greatest degree of enjoyment.

In our most rapid movements in travelling, we are often accompanied with insects making wide circuits round us, and that too against the wind. How incalculable, then, must be the celerity of motion in the muscles, that keep their wings in action! In force, how far comparatively do the muscles of the grasshopper or common flea, in making their leaps, surpass the gigantic strength of the elephant, or the energy of muscular contraction in the boa constrictor, when he crushes the bones of a large animal like the stag in his dreadful coils! What duration of action is displayed in the muscles of the limbs of the sloth, which with ease clings to the highest branches of the loftiest trees when they are lashed with the fury of the hurricane! and yet that animal has been made the object of ignorant contempt and pity, as being doomed to an imperfection in the very organization where peculiar excellency of adaptation is displayed.

The different apparatus of motion are invariably adapted in the most perfect manner to the habits and circumstances of every animal, and the construction, adjustment, and action in all their various forms and diversities equally declare the wisdom, power, resources, and beneficent provisions of the Divine Author of all, presenting to the inquiring and intelligent mind a subject for contemplation and study that is quite inexhaustible. The organs of motion even in one animal, such as man, would require for their elucidation volumes; and as knowledge advances, new and interesting views will present themselves in this admirable mechanism.

In our examination of an animal structure, in no instance do we find anything approaching to inconsistency of structure with function, but in every case the very reverse. Invariably do we perceive the most happy adaptation to, and the most perfect accordance with each other. It is only when we misconceive the purpose for which the mechanism is intended, or when, in our ignorance, we attribute to it purposes for which it never was destined, that incongruity, error, and imperfection appear.

CHAPTER XIII.

FŒTAL LIFE.

General Observations—Progress of the formation of the Egg in the Common Hen—The Molecule—All the other parts subservient to it—Incubation—Formation of the Chick in the different stages—Membranes surrounding it in the egg—Table of periods of Gestation in several Mammalia—The Vesicle—Its Passage—Arrival in the Uterus—Changes it undergoes through the various periods of Gestation, and the Functions successively called into action—Respiration in the Fœtus—Regulation of Temperature—Secretions poured into the Alimentary Canal—Circulation of the Blood of the Fœtus—Milk—Principal Constituents of—Proportion of these in different Animals—Conclusion.

In a work with the objects of the present, where the various parts of the animal machinery are intended to be described, it is necessary that some notice be taken of the earlier stages in the growth and development of the body, and of the various successive steps of its organization, at least so far as these seem to have been satisfactorily ascertained. At the same time, it appears both inexpedient and uncalled for that we should enter upon the consideration of the phenomena connected with the commencement of animal existence, still less to discuss the numerous discordant opinions that have been entertained respecting this subject; nor is it requisite to state the reasons for avoiding such disquisitions on the present occasion, since they must be obvious to every one.

The term *embryo* is applied to the new being before it arrives at any considerable degree of development,—for instance, anterior to the fifth month in the human subject;

that of *fœtus*, in the more strict acceptation of the word, designating its subsequent condition, though both terms are loosely and frequently indiscriminately used.

From the facility and accuracy with which observations can be made as to the progress of formation of the chick in the egg at any period of incubation, our most important knowledge respecting the development of the new offspring has been chiefly derived from the examination of it at different periods. Similar observations, made at different periods of gestation in mammalia, shew that the character and succession of the phenomena are in all the essential points identical. For this purpose the egg of the common domestic fowl is that which for convenience is selected. In order, therefore, to convey some notion of the manner in which the animal machinery is unfolded, the history and structure of the egg, in the first place, may be examined, that we may more readily comprehend the various changes which take place in the short period of twenty-one days, being that required for the formation of a perfect chicken out of the materials that compose it, when it has been placed under the necessary favourable circumstances.

Within the cavity of the abdomen of the common hen, and attached to the middle of the back, a cluster of globular bodies is situated, these bodies varying in their size from that of the head of the smallest pin to the full-sized yelk. These are the first rudiments of the egg. The smaller yelks are colourless and transparent, or nearly so; the larger have a more or less intense degree of yellow tint according to their size. Upon the yelks, even before they are detached from the cluster, there may be perceived a minute spot of great importance, as being the centre from which the formation of the chick subsequently commences. It is known by the name of *molecule*. The membrane of the *ovary*, as the cluster of yelks is called, is abundantly supplied with blood. On the larger yelks, numerous blood-vessels are seen distributed.

By some of these they are attached to the membrane as by a stalk. But when the yelk has acquired its full development, the vessels of attachment shrivel up, at the same time the ovarian membrane at the opposite unattached surface opens, and the yelk escapes, in the same manner as when the pea in the cod has reached maturity, the pedicle dries up, the pea is detached, and the cod opens for its escape. On the escape of the yelk, it is received by the orifice of a tube or canal, named *oviduct*. At the upper part of the oviduct, the white is added; in the middle portion the membranes of the shell and other parts are supplied; in fact the egg is completed, excepting the covering of calcareous matter which it receives towards the extremity of this tube. Occasionally the egg is laid without being furnished with the calcareous coating, when it is termed a *wind egg*.

All the different parts of the egg are subservient to the molecule, for this is the essential point from whence life has to start, and, in fact, in which life is peculiarly resident in the perfect egg. A little reflection will shew that it would have been inconsistent with the locomotive power of flying through the air for a mother of the feathered tribe to have borne within her own body her offspring till its parts were sufficiently developed for its being placed in a new and more independent condition, were there no other reason; but there are numerous other circumstances which render the connexion unsuitable between the parent and offspring, especially in other classes of animals, such as reptiles, fishes, &c. The supply of the materials, therefore, out of which the new individual is not merely to be formed, but from which it has for some time to derive its nourishment, constitutes the principal office of the parent, with the exception of the highest class of organized beings, the mammalia.

On examining a new-laid egg, we observe it covered with the porous calcareous shell, not so compact as to exclude the transmission of air. It appears wonderful that so curious a piece of mechanism as this should require no longer time than a few hours for its formation, and that too without any apparent adequate means. But although this is well deserving of our most sincere admiration, still it is a very subordinate contrivance amidst the innumerable, we may say miraculous, examples of conformation that organized structures everywhere display. Internally, the shell is lined by a membrane capable of being separated into at least two distinct layers; between these, at the larger end, there is a small quantity of air accumulated. This air varies in quantity at different periods of incubation, and at the earlier periods is the principal means of aerating the blood of the chick.

We next come to the white. This portion, it has been observed, is furnished by the oviduct in the progress of the egg along that canal. It consists of two strata, the outer being thinner than the inner, and of a less degree of consistency and viscidity. When eggs are kept for some time, the thinner part evaporates in a great measure through the shell, and the quantity of air is increased to fill up the space it occupied.

The yelk occupies the centre, inclosed in two membranes,—an external common to it and the molecule, and an internal or proper covering. It is balanced by two bodies termed poles, attached opposite to each other to the outer membrane, and terminating in flocculent extremities in the white in which they float. The yelk furnishes materials for the growth of the embryo, which, as it diminishes, receives also the white, until that is wholly expended. Finally, what remains at the end of incubation is conveyed into the intestinal canal of the chick the day before it leaves the shell, to be digested, and to supply nutriment, till the stomach is sufficiently vigorous to perform that duty. Thus we perceive that the young chick does not come into the world without provision for its nourishment, laid up for it by its parent long before the time at which it is required.

As has been stated, the molecule is the essential part. It is an exceedingly minute vesicle, containing a perfectly transparent fluid, and surrounded by a kind of halo or zone, more opaque than the surrounding parts, and termed *areola*. By some means that have not been fully ascertained, in whatever position the egg may be placed, the yelk turns round like a globe and presents the molecule uppermost, so that it is always situated nearest the breast of the mother during incubation. This turning of the yelk upon its axis, probably depends on the poles being attached higher up on the hemisphere on which the molecule is placed, and on the less specific gravity of the yelk at that part, so that they may be considered as the balancers.

Incubation of the Egg.—All that is necessary for hatching the chick in the egg is exposure to the necessary degree of temperature, namely, that of the parent. Accordingly, this temperature is frequently applied artificially. In Egypt, from time immemorial, the practice of hatching hundreds of eggs at once in properly constructed stoves has been extensively followed. It is observed that birds instinctively sit more or less closely during incubation, according to the temperature of the atmosphere. In cold climates they sit without intermission, and the duty is shared, in many instances, between both parents. While in hot countries, where the necessity does not exist, a great degree of laxity and carelessness in this respect appears to exist.

The immortal Harvey and John Hunter, both anxiously directed their attention to the formation of the chick in the egg, and made important discoveries and observations. We owe a debt to the late Sir Everard Home, for having induced that experienced, zealous, and accurate microscopic observer, Mr Bauer, to undertake this subject. No one could be better qualified for such a task. A complete master of the necessary instruments—an acute and indefatigable investigator—he started untrammelled by preconceived opinions, and without any desire to support previous doctrines, or to establish new ones, further than the facts themselves would warrant. The following account is drawn up from what he observed, according to the statement given by Sir E. Home in his Lectures on Comparative Anatomy.

In four hours after incubation, the outer edge of the areola had become enlarged, and that part of it next the molecule appeared darker. One part of the molecule appeared like a white line, the first rudiments of the embryo.

In eight hours the white line was found to be extended, and the rudiments of a brain and spinal marrow were formed, surrounded by a membrane.

The areola had extended itself, and the surface beyond the line which formed its boundary had acquired the consistence of a membrane, and had also a distinct line by which it was circumscribed.

In twelve hours the rudiments of the brain were more distinct, as well as of the spinal marrow.

In sixteen hours there was a further advance in the structure of all these parts.

In twenty-four hours a still greater increase.

In thirty-six hours the head was turned to the left side; the cerebrum and cerebellum appeared to be distinct bodies; the iris was seen through the pupil of the eye; the intervertebral nerves were nearly completely formed—those nearest the head the most distinct; a portion of the heart was seen.

At this period, apparently at the termination of the spinal marrow, a vesicle had begun to protrude. In some eggs it is seen earlier than in others, and has been observed before the heart had become visible.

In two days and twelve hours the spinal marrow was found to have its posterior part inclosed; the auricles and ventricles of the heart were seen—the auricles filled with red blood. An arterial trunk from the left ventricle gave off two large vessels, the one to the right side of the embryo, the other to the left, sending branches over the whole of the areolar membrane, which was bounded on each side by a large trunk carrying red blood; but the branches of the two trunks did not unite, there being a small space on one side rendering the circle incomplete.

In three days the outer areola had extended itself over one-third of the circumference of the yelk, carrying the marginal arteries along with it to the outer edge, but diminished in size; the brain was much enlarged, consisting of four cavities containing a fluid—the cerebellum still the largest; the spinal marrow and its nerves were more perfectly formed; the eye appeared to want only the nigrum pigmentum.

The right ventricle of the heart contained red blood; the arteries could be traced to the head; the rudiments of the wings and legs were formed; the vesicle was further enlarged, but its vessels did not carry red blood. It had forced its way out through the external covering of the yelk, and opened a communication through this slit, by which a part of the albumen was admitted to mix itself with the yelk, and gave it a more oval form. At this period the embryo is generally found to have changed its position, and to be wholly turned on the left side.

In four days the vesicle was more enlarged and very vascular, its vessels containing red blood.

The optic nerve and nigrum pigmentum of the eye were visible; the other parts had become more perfectly formed.

The outer areola had extended itself half over the yelk, which had now become still more increased in size, a greater proportion of the albumen having become mixed with it.

In five days the membranous bag that formed the vesicle had acquired a great size, and become exceedingly vascular in its coats; the yelk itself had become thinner in its consistence, more of the albumen having been mixed with it.

In six days the vascular membrane of the areola had extended farther over the yelk. The vesicle at this time had suddenly extended itself in the form of a double night-cap over the yelk, and its coverings were beginning to enclose the embryo. This change is so rapid as to be with difficulty detected. The amnion contained a fluid in which the embryo was suspended by the vessels of the vesicular membrane.

The brain had become enlarged, so as to be equal in size to the body of the embryo; its vessels were distinctly seen; the two eyes equal in size to the whole brain.

The parietes of the thorax and abdomen had begun to form; the wings and legs were nearly completely formed, as well as the bill. At this period muscular action was first noticed.

In seven days the vesicle, having extended over the embryo, had begun to enclose the areolar coverings of the yelk, and a pulsation was distinctly seen in the trunk that supplied the vesicular bag with blood. The pulsations were seventy-nine in a minute, while the embryo was kept in a temperature of 105°; but when the temperature was diminished, they ceased; when again raised to the same point, the pulsation was re-produced. By keeping it up, the pulsation continued thirty-six hours. The muscles of the limbs now moved with vigour.

When the embryo was completely immersed in water at 108°, the pulsations immediately ceased.

In eight days the anastomosing branches of the vesicular circulation had strong pulsation in them.

In nine days the vesicle had nearly inclosed the yelk, but not entirely; for when the embryo was turned upon its back, and the opposite surface examined, a portion of the yelk was uninclosed; and beyond it some of the albumen was met with not mixed with the yelk.

In ten days, divided the vesicle through both its membranes, and turned aside one half. When the embryo was taken out of the amnion, which had become full of water, the thorax was found completely formed, and the roots of the feathers were very distinct.

The contents of the egg having been much diminished during the formation of the embryo, the void space had been gradually filled with a gas. This was examined by Mr Hatchett, and found to be atmospheric air deposited at the great end of the egg, between the layers of the membrane lining the shell.

In fourteen days the yelk remained out of the body. When the thorax and abdomen were opened, and the heart as well as the lobes of the liver were turned aside, the trunks of the blood-vessels were seen arising from the heart; but as the arteries immediately after death become empty, and the veins continue full, the vesicular vein terminating in the auricle, and the areolar vein terminating in the porta of the liver, were alone conspicuous.

In eighteen days the greater part of the yelk was drawn into the body.

In twenty days the chicken was completely formed; the yelk was entirely drawn in, and only portions of the membrane belonging to the vesicle were seen externally. The yelk-bag had a narrow tube half an inch long connecting it to the intestines eight inches above the openings of the cœca into the gut; this tube entered the intestine in a direction obliquely downward.

Such is an account of the changes the egg undergoes, and the various steps of development in the chick during incubation, by one thoroughly qualified to make minute observation, and on the accuracy of whose report the utmost confidence may be placed.

We thus perceive that the perfect egg possesses in itself a separate and independent life, and that the new being is endowed with the power of forming its own blood, and of evolving the organs necessary for the exercise of its functions; the accessary conditions required being exposure to an adequate temperature, and the due supply of atmospheric air; for the functions on which the production and regulation of animal heat depend are not established in a manner to render it independent in this respect. Some of the membranes mentioned in the foregoing account deserve a little further notice.

Amnion.—As early as the eighth hour we find immediately in contact with the embryo a membrane to which this name is applied. At a later period, when the parts can be more distinctly observed, the amnion is the sac in which the chick is contained; it is a smooth secreting membrane, continuous with the external integuments and the mucous membranes of the various passages; it furnishes the fluid in which the new being swims, and is in greater proportional quantity in the earlier than in the latter periods.

The Areolar Membrane.—This appears at the same early period, the eighth hour, and corresponds with the vascular membrane in mammalia termed *chorion*. The blood-vessels first make their appearance upon this membrane, though those of the embryo itself simultaneously and independently begin to be formed. These vessels are the channels for the conveyance of materials from the yelk, according to the exigencies of the embryo.

Vesicular Membrane.—At thirty-six hours a vesicle begins to protrude from the lower extremity of the embryo, seen earlier in some eggs than in others. On the sixth day the membrane of this vesicle has extended itself like a double night-cap over the yelk on the one hand, and over the embryo on the other. Finally, it extends over the whole contents of the egg and interior surface of the shell, being abundantly supplied with blood. This appears to be the proper respiratory instrument, its extension corresponding with the enlargement, and consequently with the wants of the embryo. At first, the small quantity of air placed between the layers of the lining membrane of the shell is fully adequate to the necessities; but on the further development, this membrane lining the shell affords an expansion for the distribution of the blood-vessels, where the air, passing through the shell, may produce the required changes.

Parallel changes take place in the ovum of mammalia, and the phenomena of development are in almost every respect the same. The vesicle, however, is the only part formed by the ovary in this class; the materials of growth required, and the functions performed, especially as regards respiration, are furnished in a different manner, and carried on by other contrivances during the period of gestation, which corresponds with the period of incubation of the egg.

We are totally ignorant of the causes that tend to limit the periods of formation of the young animal, each according to its kind being restricted to certain definite circuits, within which the various organs reach their proper development. It is as impossible to obtain any explanation of the laws that regulate these periods as it is to account for the extent of the life bestowed upon each individual species. These are ultimate facts, the final purposes of which are often sufficiently obvious, while the efficient causes are, and probably ever will be, beyond the reach of human discovery. All that can be said then in respect to such matters is, that it has seemed good to the Author of all to set established boundaries to the continuance of their existence.

The periods of gestation vary much in different animals, as do also the number produced at a birth. In the human subject, its continuance is from thirty-nine to forty weeks, or from 270 to 280 days. The following table from Dr Dunglison shews the periods of gestation, and the number of young produced at a birth, in a number of animals in the class mammalia.

Animals.	Duration of Gestation.	Number of Young.
Ape............	About 9 months...	1
Bat............	......	2
Rat............	5 or 6 weeks........	5 or 6
Mouse.........	......	6 to 10
Hare...........	30 days.............	4 or 5
Rabbit.........	30 days.............	4 or 5
Guinea-pig ...	3 weeks............	5 to 12
Squirrel.......	6 weeks............	4 or 5
Mole...........	......	4 or 5
Bear...........	......	2 or 3
Otter..........	9 weeks.............	4 or 5
Bitch..........	9 weeks.............	4 to 10
Ferret.........	6 weeks.............	6 or 7
Wolf...........	10 weeks............	5 to 9
Opossum......	... ..	4 or 5
Kangaroo.....	......	1
Jackall.........	......	6 to 8
Fox............	10 weeks...........	4 or 5
Lioness.........	......	4 or 5
Tigress........	......	4 or 5
Cat............	8 weeks............	4 or 5
Seal...........	......	2
Mare...........	11 months and some days...	1
Ewe............	5 months...........	1 or 2
Goat...........	$4\frac{1}{2}$ months..........	1, 2, or 3
Cow............	9 months...........	1 or 2
Reindeer......	8 months...........	2
Hind...........	8 months...........	1 or 2
Sow............	4 months...........	6 to 10 or more
Camel.........	12 months..........	1
Walrus........	9 months...........	1
Elephant.....	2 years..............	1
Whale.........	9 or 10 months.....	1 or 2

When conception has taken place, a great alteration occurs in the whole constitution of the female in general, and in the uterus and its appendages in particular. Immediately a determination of blood takes place to this organ; its internal surface has an inflammatory appearance; a quantity of gelatinous fluid plugs up its orifice, and from its surface a membrane is formed. For the first two or three months it undergoes little change in form or bulk. About the fourth month it begins to ascend, and to enlarge in its diameters. This it continues to do up to the eighth month, when it is found to have reached considerably above the navel; it then fills the whole anterior part of the cavity of the abdomen, crowding the viscera behind it, and in the flanks. During the ninth month its base somewhat descends, and projects forwards. In all this period of enlargement, a very great quantity of blood circulates through its walls, and its muscular fibres become more and more increased in number and strength, that it may be prepared for the duty it has to perform in the expulsion of its contents.

Even before the ovum reaches the womb, there is thus prepared for it a proper receptacle, where it can be conveniently lodged, cherished, and brought to maturity, and lastly, when it has arrived at full development, for powerfully expelling it.

The ovum presents merely the appearance of a globular transparent vesicle filled with limpid fluid. It is supposed to arrive at the uterus on the seventh or eighth day, having traversed a canal extending from the uterus about four or five inches in length, and terminating in a wide-fringed mouth, which floats loosely in the cavity of the abdomen. At first the ovum is without any adhesion to the internal surface of the uterus.

Progress of Gestation.—Up to the twenty-first day little alteration can be observed in the ovum. About this period the fluid it contains appears turbid, and in the midst of it there is an opaque spot suspended; the embryo, when immersed in spirits, becomes more perceptible, appears somewhat of the shape of an ant, and of little more consistence than the surrounding fluid.

About the forty-fifth day the form of the embryo is more determined; the head is very large in proportion to the rest of the body; blackish points or lines indicate the presence of the eyes, nostrils, and mouth; the limbs appear like minute buds; length about ten lines.

Second month.—Eyes enlarged in every diameter; the eye-lids appear, and are transparent; the nose begins to stand out; the mouth increases and becomes open; the fingers and toes are distinct; the heart is largely developed.

Third month.—The eye-lids developed and firmly closed; the pavilion of the ear becomes perceptible; the lips approximate, and close the mouth; the brain and spinal marrow pulpy, but considerably unfolded; the heart beats forcibly; the liver very large, soft, and pulpy.

Fourth month.—All parts acquire much development and character, except the brain and liver, which do not increase much in bulk but in consistence; the muscular system, begun to be developed in the third month, is now distinct, and slight movements take place.

Fifth month.—Increase in every part has advanced, particularly in the muscles, which produce distinct and unequivocal motions; the eye-lids are glued together; the head is still very large in proportion to the rest of the body, and covered with short silvery hairs.

Sixth month.—The skin delicate, smooth, and of a purple colour, cuticle distinguishable from the true skin; the integuments seem plaited, from the absence of subjacent fat; the nails make their appearance, and towards the close of the month are somewhat firm. Should the fœtus be born now, it may breathe and faintly cry, but it dies in a few hours.

Seventh month.—All the parts are better proportioned: the eyelids begin to be opened, and the membrane which ·usly closed the pupil begins to be absorbed; fat is deposited more abundantly, and consequently the form is more rounded; the follicles of the skin secrete a fluid which renders the waters turbid. If birth occurs at this period, great care in nursing for the next two months will be necessary for the preservation of life.

Eighth month.—The increase is more in breadth than in length, and all the parts attain firmness, consistency, and strength.

Ninth month.—The organs of the fœtus acquire the necessary degree of development, in order to fit them for entering upon a new state of existence. The weight of the body is usually from six to seven pounds, and its length from twelve to twenty inches.

The appendages of the fœtus consist of two membranes, the *chorion* and *amnion*, and of the *umbilical* or *navel cord*. The chorion is the exterior membrane in contact with the internal surface of the uterus. In the earlier stages, it is furnished with a shaggy covering, which gradually disappears. In further progress, numerous blood-vessels shoot forth from the shaggy surface, and apply themselves to the lining membrane of the uterus, and where they come in contact with this membrane, vascular processes are projected. Thus two sets of vessels are formed—one set belonging to the fœtus, and the other to the mother; these interlace with each other, without, however, forming actual communications with one another; together they form what is termed the *placenta*, an organ of the most essential importance in the fœtal economy, since it is the means of intercourse with the mother. The placenta makes its appearance towards the end of the second month. At this time it covers two thirds, or at least one half of the ovum; at the full period not more than one fourth. The chorion can be traced along the cord as far as the navel, where it is lost. Up to the end of the third month, the two membranes are separated from each other by a quantity of fluid, which then disappears, so that they come in contact.

The *amnion* is the innermost of the two membranes. It is somewhat elastic, and of a whitish colour, becoming thicker and firmer as pregnancy advances. It is continuous with the common integuments and mucous membranes of the fœtus. From its internal surface are derived the waters surrounding the fœtus. These waters are in the inverse proportion to the advancement of gestation. Calculated as they are to afford equable support in every direction, to sustain the tender fabric in its first formation, and to obviate the effects of concussion from without, we perceive these waters are of essential importance. Accordingly, at first, when all the parts are most delicate, so are they in greatest quantity, in order to afford defence and protection; but as the organs gain firmness and strength, they proportionally diminish.

The *umbilical cord* consists of the blood-vessels passing between the fœtus and the placenta; it varies greatly in length in different cases; in some instances it is not more than a few inches, while in others it extends to five or six feet.

In the higher classes of animals, before birth, the function of respiration does not exist in the same manner that it is exercised after that event, but still an analogous function is carried on, chiefly through the placenta, where the blood in the mammalia becomes exposed to the aerated blood of the mother; in so far, therefore, being similar to what takes place in fishes, where the blood is changed on exposure to the aerated water while passing through the gills. In birds, towards the latter period of incubation, the fœtal blood is more directly exposed to the influence of the air, where it is distributed upon the membrane extended over the internal surface of the shell, through the pores of which noxious gases make their escape, and the atmospheric air enters; thus the function of breathing is performed in a modified form, before the chick leaves the shell, and at the commencement of the process, from the air lodged between the layers of the membrane of the ʼl placed at the larger end.

Although the chemical changes that necessarily occur in the alteration the fluids undergo in the various processes carried on in the fœtal state, must involve the extrication and absorption of caloric, and consequently to a certain extent the temperature, yet they do not take place in such a degree or manner as to sustain and regulate the temperature requisite for the due exercise of the functions of life. Accordingly, in birds, heat is imparted externally during the process of hatching, and in mammalia the fœtus participates of the heat of the mother.

In birds, the materials for building up the different parts of the frame are stored up in the egg, and even in such quantity that when the perfect chicken is formed a residue remains, which we have seen is conveyed into the intestinal canal, where it becomes digested, and forms the first food presented to the digestive apparatus. In mammalia, as the fœtus is developed, materials are furnished in due quantity, and in the condition suitable to its exigencies. Thus the function of digestion, strictly speaking, does not commence till after birth; a considerable quantity of fluids, however, from various sources, and especially from the liver, are poured into the alimentary canal; part of these may undergo a change somewhat analogous to digestion, and be reintroduced into the system, while the remainder accumulates in the bowels, till they can be discharged after birth.

An idea of the condition of the fœtus can be more easily and more correctly obtained by studying the manner in which the blood circulates in its system than in any other way. Two kinds of circulation exist in the fœtus—the one belonging to its own body in particular, the other carried on through the placenta, for effecting the necessary changes on the blood, and whereby fresh matter is introduced into the system, derived from the mother. Beginning with the course of the blood at the placenta, we find collected from that body numerous veins, which unite into one trunk, named the umbilical vein. This vein passes along the cord, and enters the abdomen at the navel; from thence it proceeds upwards to the liver, where it is joined by the porta from the viscera; the greater portion of the blood circulates through the liver, but part enters directly the ascending cava by a channel peculiar to the fœtus, and the portion that circulated through the liver is likewise poured into the same vessel, to be conveyed into the right auricle of the heart. The greater portion of the blood in this way is filtered through the liver, which is correspondently of a large proportional size in the fœtus. Here a considerable quantity of fluid is separated from it in the earlier periods, free from any bitterness; but towards the full period it presents the usual characters of bile. The bile may in this condition be considered as an excretion for the purification of the blood, though at the same time it may, when poured into the intestine, serve for exercising the function of digestion for the first time.

The fœtal heart presents a peculiar organization; the right and left auricles freely communicate by an oval aperture, whereby the blood of the ascending cava passes directly to the left side, to be transmitted into the aorta, the great arterial trunk of the system. Into this oval aperture the blood of the ascending cava is directed by a valvular apparatus, while that of the descending cava, being the blood from the head and superior limbs, as also the proper vein of the heart, pour their contents into the right ventricle, to be propelled into the pulmonary artery. This artery divides into three branches—two lateral ones for the lungs. The lungs are only developed towards the latter period of gestation, as their function is only called forth after birth. The arterial tubes they receive are correspondently small, while the third branch of the pulmonary artery, peculiar to the fœtus, is large, and joins the aorta after the arteries from the head and superior parts of the body have been sent off. By this arrangement, the fresh blood from the placenta, brought by the ascending cava, flows directly to the left side, and that from the upper part of the body is carried into the descending aorta, by which the greater part of the blood is conveyed to the placenta. Moreover, we perceive that both ventricles co-operate in propelling the blood into the aorta, that it may be transmitted, not only to the system, but along the cord, and subsequently through the placenta.

The aorta appears to divide in the loins into two large arteries, which, after giving off branches to the pelvis and lower limbs, ascend by the side of the bladder to the navel, pass along the cord, and distribute their blood to the placenta. There is no direct vascular connexion between the mother and the fœtus. Their circulations are carried on independently of each other,—the pulsations of the fœtus being nearly double those of the mother; and if the mother be bled to death, the vessels of the fœtus remain fully distended, suffering no loss. The mode of connexion subsisting between them consists in the vessels of the one, in the form of bundles or clusters, being received into corresponding crevices of the other. A very large quantity of blood circulates through that part of the uterus to which the placenta is attached, affording to the fœtal blood the means of effecting the necessary changes, and presenting additional materials required and taken up by the vessels of the fœtus. Along with these fresh materials poisons and other matters gain entrance into the fœtal system, by being absorbed from the blood of the mother; if she therefore labours under an infectious disease, the same in this way may be imparted to the fœtus. Such facts show how important must be the healthy condition of the mother, that proper and healthy materials may be furnished to the offspring.

At last the period arrives when the body has reached that degree of development that enables it to exercise the functions in a new sphere of existence, and birth takes place. In mammalia there is provided by the system of the mother a nutritious fluid, expressly formed for the young and delicate organs of digestion, containing the elements of all that for some time is required for the growth and enlargement of the different parts of the frame.

This fluid, the milk, consists principally of a modification of albumen termed cheese or caseum; an oily matter, butter; a peculiar form of sugar, along with a considerable quantity of watery fluid termed whey or serum. MM. Deyeux and Parmentier, after a great number of experiments, give the following classification of six kinds of milk in respect to the relative proportion of the chief constituents in each :—

Caseum.	*Butter.*	*Sugar of Milk.*	*Serum.*
Goat	Sheep	Woman	Ass
Sheep	Cow	Ass	Woman
Cow	Goat	Mare	Mare
Ass	Woman	Cow	Cow
Woman	Ass	Goat	Goat
Mare	Mare	Sheep	Sheep

From what we have now seen of the animal body, it will be perceived that from its first appearance, like a drop of limpid water, to the extreme of old age, the solids gradually gain upon the fluids, until at last a stop is put to the working of the machinery; the living principle that hitherto protected the frame, yields it up to the influences that regulate dead inert matter; part flies off in the gaseous form, part is resolved into fluids, and part crumbles into dust; while the immortal and responsible spirit of man returns to Him who gave it.

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